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Final Technical Report
October 1976

ATEC DIGITAL ADAPTATION STUDY
ATEC Applicability and Adaptations

Honeywell Inc

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ROME AIR DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
GRIFFISS AIR FORCE BASE, NEW YORK 13441

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The ATEC Digital Adaptation Study sought to answer the questions: (1) What should be monitored for PA/FI/TA of the FKV system; (2) What measurements, data collection, and analysis should a monitor system perform, (3) Is the ATEC system and equipments applicable in satisfying the measurement and analysis requirements, either unmodified or with minor adaptations, and (4) Can an ATEC/FKV demonstration be performed: The study addressed each of these questions, in turn, and the answer is that the ATEC system and equipments, augmented by minor hardware and software adaptations, can satisfy all the

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PA/FI/TA monitoring system requirements for the FKV digital transmission system. An ATEC monitoring system for the entire FKV system is presented and operational characteristics dealing with all aspects of the monitoring system are presented. In addition, an ATEC/FKV demonstration configuration is presented which would enable the validation of the ATEC digital transmission system monitoring capability through field testing and data collection on a link within the FKV system.

SUMMARY

The ATEC system and equipments were studied and analyzed in order to determine their applicability and/or adaptability in satisfying the monitoring system requirements for PA/FI/TA of the FKV digital transmission system as identified in Volume I of this report. The results of the investigation revealed that the monitoring system requirements are satisfied by the existing ATEC equipment, augmented by minor hardware and software adaptations.

The hardware adaptations permit the monitoring of the 3 level partial response radio baseband signal plus the counting and/or latching of transient system and equipment events, e.g., multiplexer frame errors and reframes.

The software adaptations provide for FKV system monitor point scans, operator interaction, data analysis, and CRT display generation.

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Section 1

INTRODUCTION

This volume addresses the applicability of ATEC system components to the problems of digital transmission system monitoring in general and the FKV system in particular.

The ATEC components are examined in Paragraph 2.1 with particular attention directed toward those equipments and features which appear to have digital systems application. From this a list of equipment was derived for potential FKV systems application.

In Paragraph 2.2, the capability and desirability of monitoring specific types of parameters, delineated in Section 4, Paragraphs 4.1.5, 4.1.6, and 4.1.7 of the Statement of Work for this study are discussed.

Next, in Paragraph 3.1, candidate hardware adaptations of ATEC equipment to improve its potential digital monitoring capabilities are considered. From this group of potential adaptations, those were selected which offered the most capability in monitoring the FKV system. From these, a final choice was made to recommend, for the FKV demonstration program, only those adaptations whose field testing is essential to determining the capability of the ATEC system to monitor the FKV network. These adaptations are discussed in considerable detail in Paragraph 3.2.

Data processing requirements to perform the task of digital systems monitoring are examined in Paragraph 3.3. The PATE is recommended for use as the system central processor, and its software requirements are outlined therein.

Paragraph 3.4 discusses the outputs provided by the monitoring system to the communications system operators. Each type of display is examined, its contents discussed, and its contribution to the system monitoring task outlined.

Section 2

ATEC APPLICABILITY FOR DIGITAL TRANSMISSION SYSTEM MONITORING

2.1 ATEC EQUIPMENTS UTILITY IN DIGITAL PERFORMANCE MONITORING

This report section introduces the principal ATEC equipments and briefly summarizes their functional configuration and operating characteristics.

Applicability of the equipments for digital transmission system monitoring, in accordance with the monitor concepts advanced in Volume I of this report, is addressed for each ATEC equipment type.

2.1.1 Monitor Telemetering Set (MTS)

The Monitor Telemetering Set (MTS) provides automated monitoring of dc voltages, voice frequency signal levels, and alarms. The MTS provides for the acquisition and measurement of analog signals for applications including in-service or out-of-service circuit testing. It also performs alarm scanning to collect, display, and transmit the status of two-state alarms. Control of the MTS is provided by an associated teletypewriter (TTY), Teletype Model ASR-37, which provides hardcopy results of the various measurements and provides the means for operator control through the CPMAS Nucleus Subsystem.

The MTS is used by Technical Control Facility (TCF) personnel to obtain performance checks of active digital data circuits, VF signal levels, and alarms without interruption of normal traffic flow.

The MTS is composed of two groups, the Alarm Group and the Measurement Group. The following equipments are in the Alarm Group: Alarm Scanner (AS), Alarm Display (AD), and Master Alarm Display (MAD). The Form A and C Scanners and the Measurement and Acquisition Control (MAC) are in the Measurement Group.

The Alarm Scanner has the capability of scanning up to 50 alarms. Each Alarm Scanner contains from 1 to 5 alarm PC cards. Each card is capable of sensing 10 alarms. The Alarm Display has the capability of displaying the status of up to 50 alarms. Each Alarm Display contains from 1 to 5 alarm display cards. Each card is capable of displaying the status of 10 alarms. The Master Alarm Display is capable of selecting and displaying the alarm states of a single Alarm Scanner from a group of 10 Alarm Scanners.

From 1 to 5 scanners can be used with a Measurement and Acquisition Control. Each scanner can contain up to 10 relay cards. Each card can contain 10 Form A or 5 Form C relays.

In addition to acquiring dc and VF signals for measurement, the MAC acts as the interface and/or controller for the MTS measurement options listed below.

a. Pilot Monitor

b. Noise Stop Filter

c. Baseband Monitor

d. Reflected Power Sensor

e. Switching/Loopback Group

f. Noise Loading Group

g. Idle Line Seizure Controller

h. Voice Data Combiner

A description of each option (except baseband monitor) is contained in Paragraph 2.1.8. The baseband monitor is discussed in Paragraph 2.1.7.

2.1.1.1 Alarm Group

The functional configuration of the alarm group major equipments is shown in Figure 2-1. The units which are required in a computer-controlled system are the Master Alarm Display and the Alarm Scanner.

Modularity of the system is as follows: one Master Alarm Display can collect data from one to ten Alarm Scanners; each scanner may have from one to five cards; each card carries ten alarm inputs. All units fit in a 19" rack.

2.1.1.1.1 Alarm Scanner

The alarm inputs can be contact closures, ac voltages, or dc voltages, with not more than four voltages per card. The sense of the alarm can be normally open or closed or, with voltages present or absent. Voltage alarms must be able to supply 10 milliamperes through 500 ohms (dc) or 527 ohms (ac).

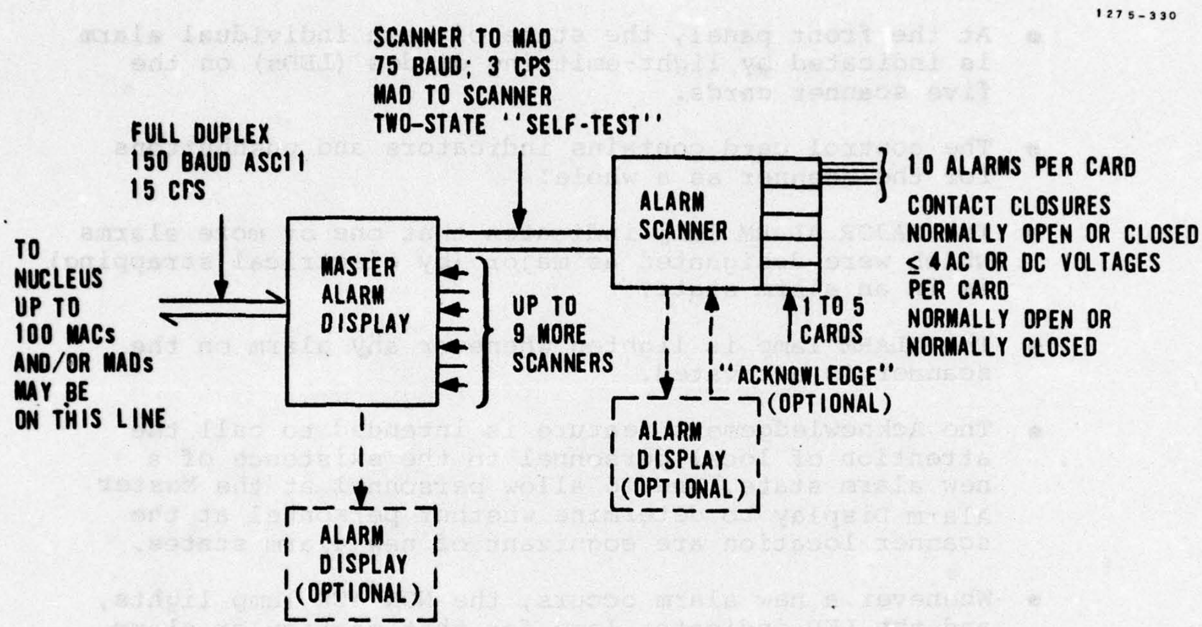

FIGURE 2-1. ALARM GROUP FUNCTIONAL CONFIGURATION

Figure 2-2 shows the alarm scanner. Functional characteristics of the unit include:

- At the front panel, the state of each individual alarm is indicated by light-emitting diodes (LEDs) on the five scanner cards.
- The control card contains indicators and pushbuttons for the scanner as a whole.
- The MAJOR ALARM lamp indicates that one or more alarms which were designated as major (by electrical strapping) is in an alarm state.
- The ALARM lamp is lighted whenever any alarm on the scanner is activated.
- The Acknowledgement feature is intended to call the attention of local personnel to the existence of a new alarm state, and to allow personnel at the Master Alarm Display to determine whether personnel at the scanner location are cognizant of new alarm states.
- Whenever a new alarm occurs, the NON ACK lamp lights, and the LED indicator lamp for that particular alarm blinks. Simultaneously, a bit is placed in the outgoing data to indicate that a new alarm exists unacknowledged by local personnel.
- To acknowledge the alarm, the ACK pushbutton is depressed. This turns off the NON ACK lamp; causes the new alarm LED indicator lamps to revert to a steady "ON" state, and causes the "nonacknowledged" bit in the outgoing data stream to revert to normal.
- The acknowledgement function may also be wired so that it can be operated from an Alarm Display unit, remote from the scanner itself.
- "Self-Test" tests the LEDs and some of the internal logic. A successful test will cause all of the LED indicators to reverse their state.

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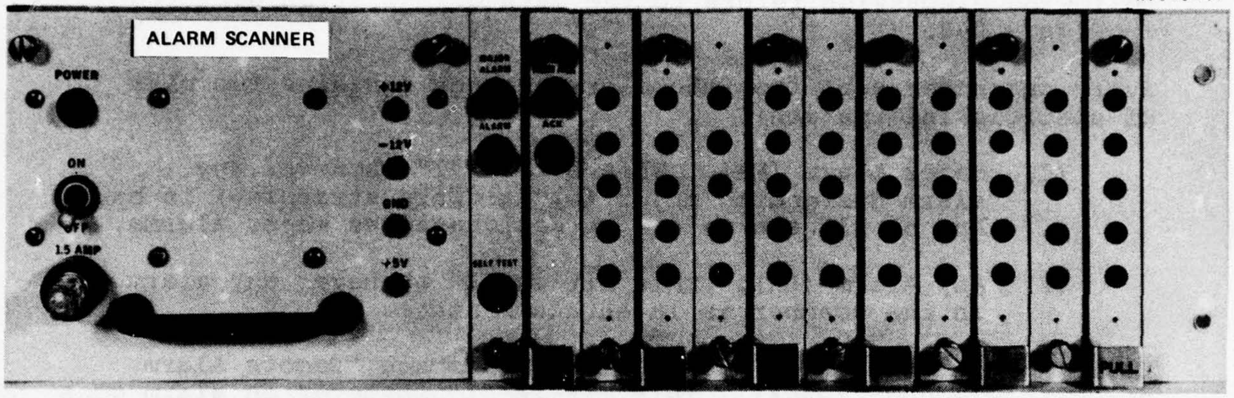

FIGURE 2-2. ALARM SCANNER

Data flow from the Alarm Scanner uses two types of 10-bit characters, a begin character and a detailed data character. These characters are sent at a rate of three per second, with 15-bit intervals of mark hold separating the characters. The following discussion refers to the data organization depicted in Figure 2-3.

Every character sent from the alarm scanner contains two bits of specific information:

(1) Major Alarm (MA). This bit is "1" whenever any alarm designated major (by hardware strapping) is on. Any or all alarms can be designated as major alarms.

(2) Any Alarm (AA). This bit is "1" whenever any alarm in the scanner is in an alarm state.

Every "Begin" character has a bit to indicate "Remote Alarm not Acknowledged" (NACK). This bit is "1" whenever an alarm goes on after an acknowledgment pushbutton on the front panel has been actuated.

A begin character is followed by data characters, two for each card on the scanner with the last half of the last card sent first. When the first five alarms of the first card have been scanned, the begin character is again transmitted and the cycle repeats.

The alarm state transmitted is that existing at the moment data is read from the card for transmission.

The time required for cycling is, in bit intervals, 25 +50C, where C is the number of cards. In seconds, at 75 baud, this is

$$\frac{1}{3} + \frac{2}{3}C, \text{ or } \frac{1}{3} + \frac{2N}{30}$$

where N is the number of alarms and can take values of 10, 20, 30, 40 or 50.

Since "any alarm" (AA) and "major alarm" (MA) indicator bits occur every 10-bit characters and the 10-bit characters are separated by 15-bit times, these alarm indicator bits occur every 25-bit times. At a given time, an alarm bit is equally likely to occur at any location; hence, the time for the appearance of AA or MA in the bit stream is given by a

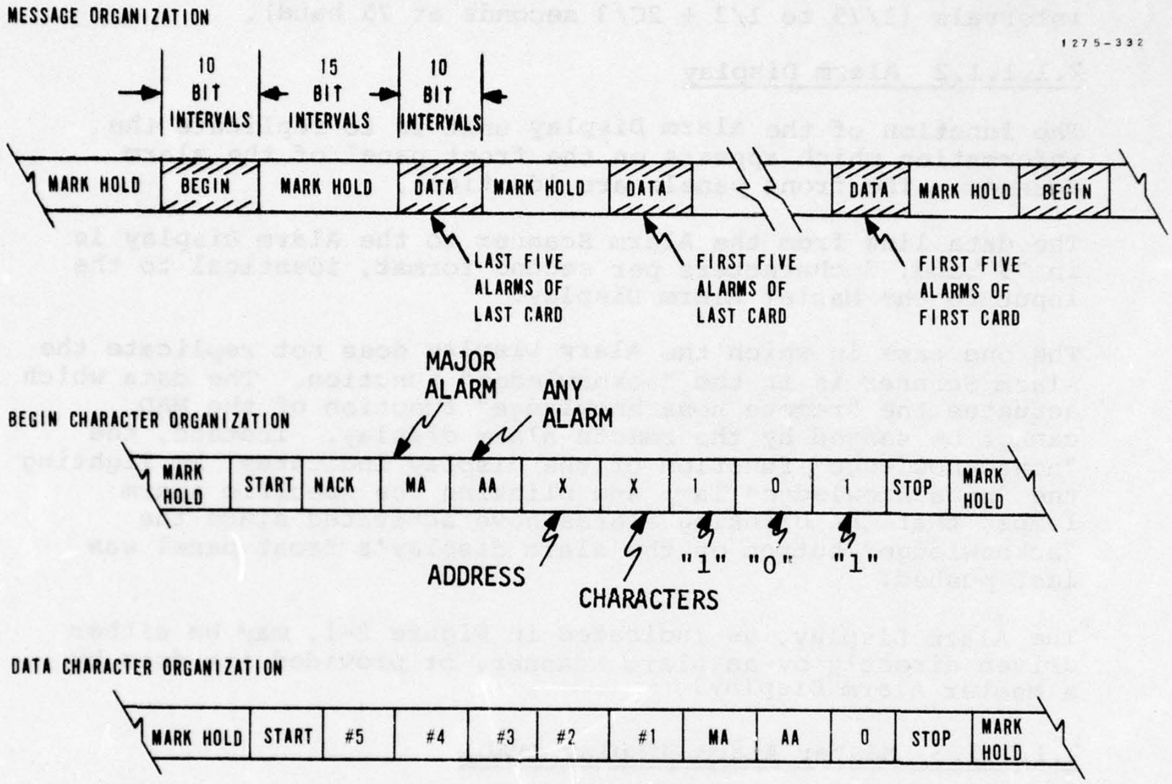

FIGURE 2-3. ALARM SCANNER TO MAD AND ALARM DISPLAY ORGANIZATION

uniform probably density function from 1 to 25-bit intervals (1/75 to 1/3 second at 75 baud). The same argument may be applied to show that the time between the existence of an alarm and the appearance of the alarm indication (in the data stream) is a random variable between 1 and 25 +50C bit intervals (1/75 to 1/3 + 2C/3 seconds at 75 baud).

2.1.1.1.2 Alarm Display

The function of the Alarm Display unit is to replicate the information which appears on the front panel of the alarm scanner. The front panels are identical.

The data line from the Alarm Scanner to the Alarm Display is in 75 baud, 3 characters per second format, identical to the input to the Master Alarm Display.

The one case in which the Alarm Display does not replicate the Alarm Scanner is in the "acknowledge" function. The data which actuates the "remote nonacknowledge" function of the MAD cannot be sensed by the remote alarm display. Instead, the "nonacknowledge" function of the display indicates, by lighting the "nonacknowledge" lamp and blinking the specific alarm lamps, that the blinking alarms have activated since the "acknowledge" button on the alarm display's front panel was last pushed.

The Alarm Display, as indicated in Figure 2-1, may be either driven directly by an Alarm Scanner, or provided its data by a Master Alarm Display.

2.1.1.1.3 Master Alarm Display (MAD)

The Master Alarm Display scans the incoming data lines from the Alarm Scanners for information, some of which is used only locally, and some of which is available to the CPU. Local functions and CPU functions operate independently of each other.

One device scans for begin characters, looking for "remote not acknowledged" bits. These are used to indicate, by scanner, on front panel lights, a nonacknowledged alarm.

Another device scans for "any alarm" bits. These are used to indicate, by scanner, on front panel lights the existence of one or more alarm states on that scanner.

A third device scans for "major alarm" bits. These indicate, at the front panel, those scanners which hold one or more major alarms, in a manner analogous to "any alarm." However,

for CPU connection, the major alarm status of the ten scanners is stored. Two consecutive status checks by the major alarm detection circuitry, which indicate a change of state from that stored, will trigger a "major alarm state change" response to a poll.

Individual alarm scanners may be selected for local display of their states on an associated alarm display.

The ways in which the Master Alarm Display is used may be clarified by describing the functions on its front panel, depicted in Figure 2-4:

- Each column of indicators and pushbuttons represents status of one alarm scanner.
- The upper lamps (MAJOR ALARM) when lighted, indicate that that particular scanner holds one or more major alarms.
- The second row of lamps (ALARM) indicate the existence of any alarm on that scanner, major or not.
- The third row of lamps (NON ACK) are indications of the nonacknowledgement of an alarm at the scanner location.
- The ALARM SCANNER SELECT row of pushbuttons selects the detailed status of a scanner for display on an associated alarm display when operating in the "manual" mode.
- SELF TEST performs a self test on the selected alarm scanner in the fashion as described under the alarm scanner section (Paragraph 2.1.1.1.1).
- LAMP TEST tests the lamps on the master alarm display.
- The SELECT CONTROL MODE toggle switch controls the method of displaying information on an associated Alarm Display. In the manual mode, the pushbuttons on the ALARM SCANNER SELECT row determine which scanner's status is selected.

The MAD, due to its method of operation, has various internal delays in obtaining information when requested by the CPU.

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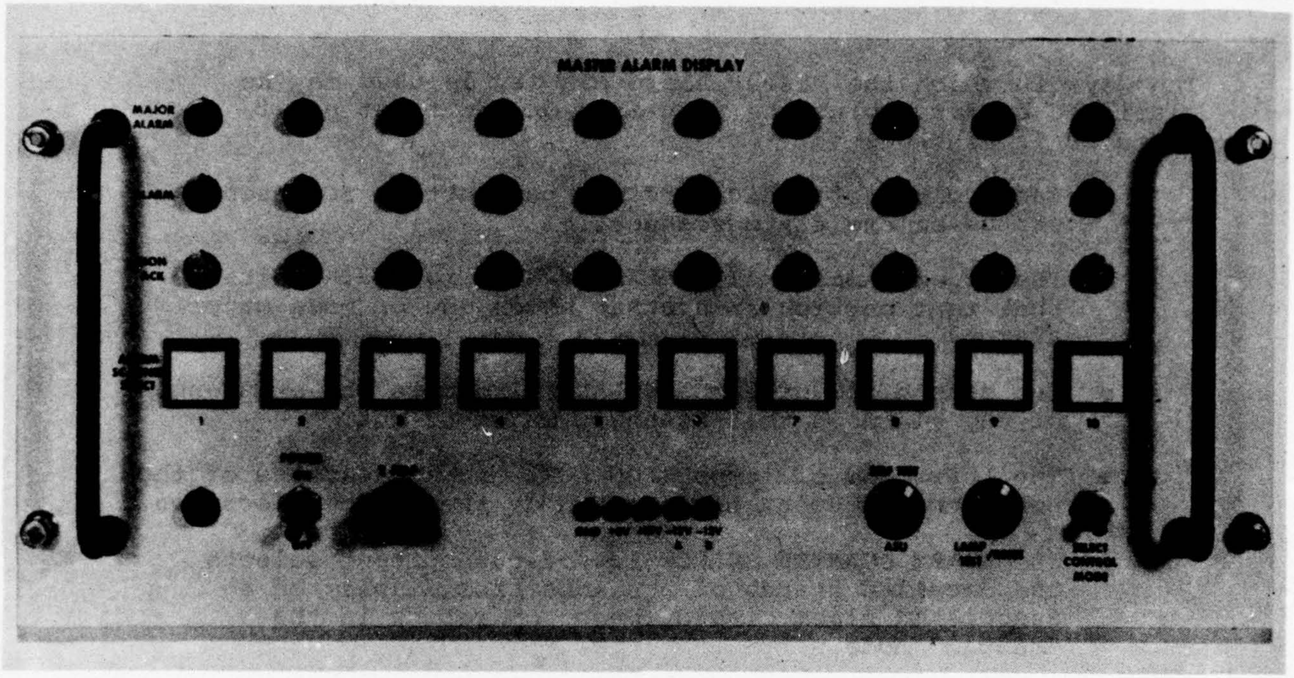


FIGURE 2-4. MASTER ALARM DISPLAY

Since all major alarm status, by scanner, is held by the MAD, the response to a poll is immediate. However, since one device in the MAD serially detects major alarm status on all scanners, the information held by the MAD is old. The time required to detect all major alarms by the MAD is 25-bit intervals multiplied by S, where S is the number of scanners. The time to detect a particular major alarm is a random variable from 1 to 25S bit intervals. In order to generate a change of state, the new major alarm condition must exist for two successive looks at a scanner line. The time to observe two looks is the time for one look plus 25S bit intervals or a random variable from 1 + 25S to 50S bit times. The mean value of the random variable is then

$$\frac{50S + 25S + 1}{2} = \frac{75S}{2} + \frac{1}{2} \text{ bit intervals.}$$

Hence, the mean time to detect a major alarm change by the MAD is approximately 38S bit times.

When the MAD is requested to furnish the complete alarm status of a scanner by the CPU, the device which detects individual alarm states must wait until it senses a "begin" character at the line from the scanner. The delay in sensing "begin" is a random variable with a uniform distribution from 1 to (25 + 50C) bit intervals on the scanner lines, or

$$\frac{1}{75} \text{ to } \left(\frac{1}{3} + \frac{2}{3}C\right) \text{ seconds}$$

at 75 baud. The first data word is detected 25 bits later, and, the process of reading data into the MAD begins.

The MAD reads the status of the scanner into its internal memory. When the next "begin" code is sensed, all data from that scanner has been received, and the process of sending data to the CPU/TTY begins. Time for loading the memory is the time between the beginning of one begin word and the end of the next, which is 10 + 25 + 50C bit intervals, or approximately 7/15 + 2C/3 seconds at 75 baud.

The time interval between the receipt of an alarm status request and readiness to send data to the CPU is composed of the following elements:

(a) 1/75 to (1/3 + 2C/3) seconds, at 75 baud, random delay of AS.

(b) (7/15 + 2C/3) seconds, at 75 baud, time to load MAD memory.

Note that, due to the hardware operation of the MAD, internal processing delay and time to load the CPU from the MAD is more than an order of magnitude less than the lower limits of the numbers in (a) and (b), above, and consequently may be ignored.

2.1.1.1.4 MAD - CPU Interaction and Timing

The MAD is designed to speak only when spoken to. It echoes back every character received to allow check for transmission errors.

This discussion will concentrate only on actual data requests; communications control and self-test are disregarded.

The three commands discussed are enquiry ($), major alarm request (M), and a request to read out all alarms in a particular scanner (A + scanner number).

(a) Enquiry ($) generates a one-character response if no scanners have shown a change of state of major alarm status in two consecutive looks by the MAD.

If a scanner has changed status by going from "no" to "one or more" major alarms, or vice versa, a message is sent back indicating the major alarm status of each scanner.

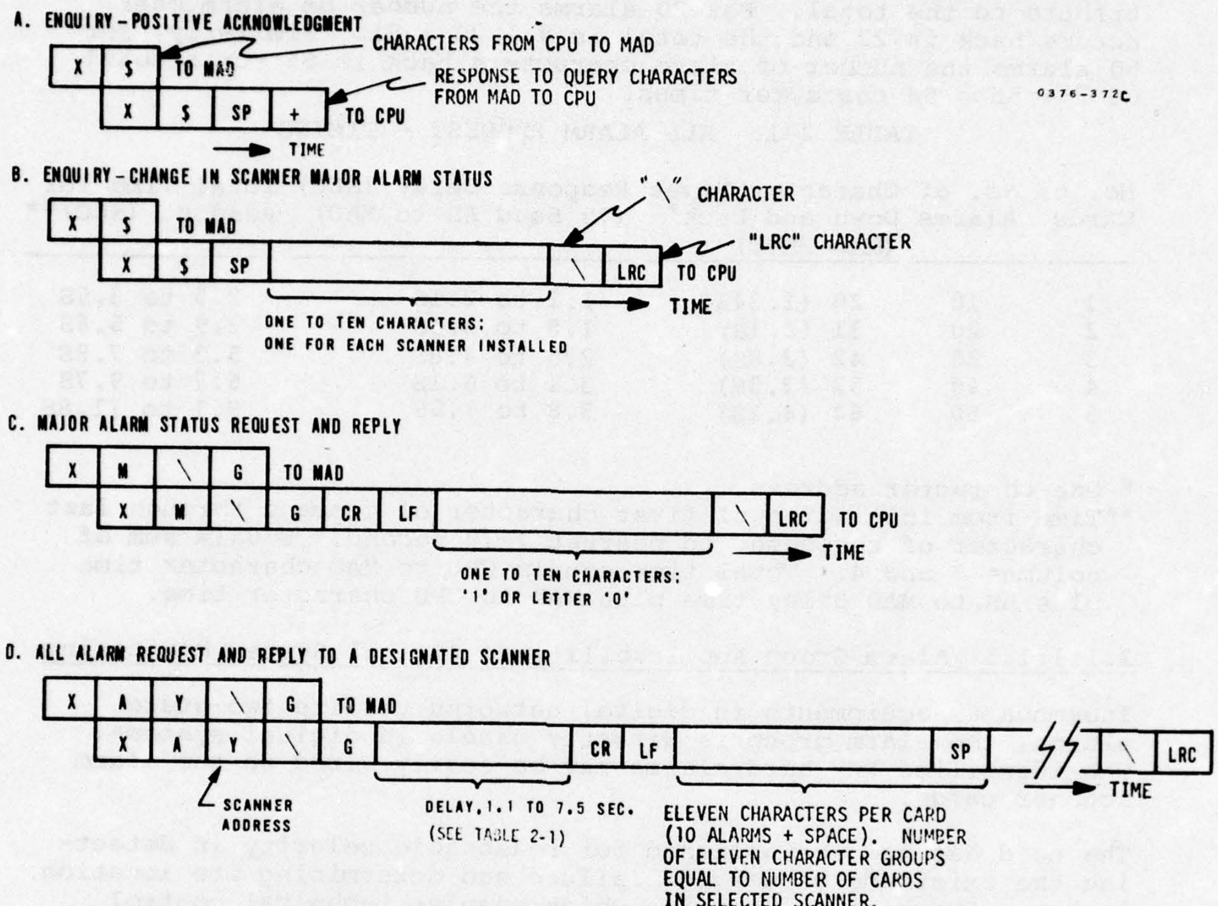
(b) Major Alarm Request (M) generates a reply which indicates the major alarm status of each scanner. A letter "O" (not zero) character indicates that a scanner holds no alarms which have been strapped as major; a "1" indicates that the scanner holds one or more major alarms.

(c) All Alarm Request for a designated scanner (Ay) (y is scanner number) generates a reply which provides, in groups of 10, the status of each alarm on the scanner.

The MAD to CPU message interaction is shown graphically in Figure 2-5. Table 2-1 tabulates times for "all alarm" request.

The total readout time is composed of the time required to transmit characters down and back plus response delay. The response delay varies between 1.1 and 7.5 seconds depending upon the number of scanned alarms. The number of character times for 10 scanned alarms is 20 (Figure 2-5) and is broken down into:

1 character time down - character X
8 character times back- characters X,A,Y,\,G,CR,LF,\
11 alarm characters back
20 character times, total



NOTE: "X" denotes any character and is MAD address.

FIGURE 2-5. MAD-CPU MESSAGE INTERACTION

For Digital ATEC parity is checked on each character. The LRC is not employed as a character parity check and does not contribute to the total. For 20 alarms the number of alarm characters back is 22 and the total is 9 + 22 = 31. Similarly, for 50 alarms the number of alarm characters back is 55 for a total of 9 + 55 = 64 character times.

TABLE 2-1. ALL ALARM REQUEST - TIMING

No. of Cards	No. of Alarms	Character Times Down and Back* (MAD-PATE)	Response Delay (SEC) (75 Baud AS to MAD)	Total Time for Readout (SEC)**
1	10	20 (1.34S)	1.1 to 2.1S	2.5 to 3.5S
2	20	31 (2.1S)	1.8 to 3.5S	3.9 to 5.6S
3	30	42 (2.8S)	2.5 to 4.8S	5.3 to 7.8S
4	40	53 (3.5S)	3.1 to 6.1S	6.7 to 9.7S
5	50	64 (4.3S)	3.8 to 7.5S	8.1 to 11.8S

* One character address.

**Time from initiation of first character of command through last character of response, to nearest 1/10 second. Equals sum of columns 3 and 4. Total time equals CPU to MAD character time plus AS to MAD delay time plus MAD to CPU character time.

2.1.1.1.5 Alarm Group Applicability to Digital System Monitoring

Inasmuch as equipments in digital networks utilize two-state alarms, the alarm group is directly usable in digital systems. The identified FKV hard alarms may be easily wired to the alarm scanner cards.

The need has been established for reasonable celerity in detecting the existence of service failure and determining its location in the network to a precision which enables technical control initiation of altroute actions. This need can be satisfied in two ways: By establishing a bank of alarm displays which replicate the alarm status of the system, or by frequent CPU scanning of major alarm states. For FKV application, the former method has been selected. However, as has been developed in Volume I, the CPU should maintain cognizance over the status of alarms. For this application, the Master Alarm Display can serve as a data concentrator, enabling the CPU to determine alarm status when required through a single data port.

Applicability of the alarm group to digital system monitoring will be pursued no farther in this section; details of its application, however, are threaded throughout the body of this report.

2.1.1.2 Measurement Group

2.1.1.2.1 Measurement Acquisition and Control (MAC)

2.1.1.2.1.1 Description

Functionally, MAC performs the following tasks:

- Selects and measures dc voltages.
- Selects and measures VF voltages, with control capability to loopback and terminate lines brought to "C" scanners.
- Transfers commands to, and data from, other devices termed "options" such as those listed in Paragraph 2.1.1.
- Acts as a communications interface between the local TTY and the remote TTY/CPU.

Only one task with one input (or, with specially configured VF lines, one set of inputs) can be performed at any one time. Control may be exercised from the front panel; a local teletype, and a remote teletype or CPU. Figure 2-6 shows the interfaces.

The MAC can accept a command to measure an individual input port, or it can be set to scan and measure inputs sequentially, in order of scanner address numbers. No internal inhibitions are provided to preclude VF measurements on a dc line or vice versa.

A photograph of the MAC is shown in Figure 2-7.

2.1.1.2.1.2 VF Capabilities

The MAC can perform the following operations on VF lines routed through appropriate scanners:

- Measure VF channel levels between -60 and +20 dBm to an accuracy of ±0.5 dB, in the following configurations:

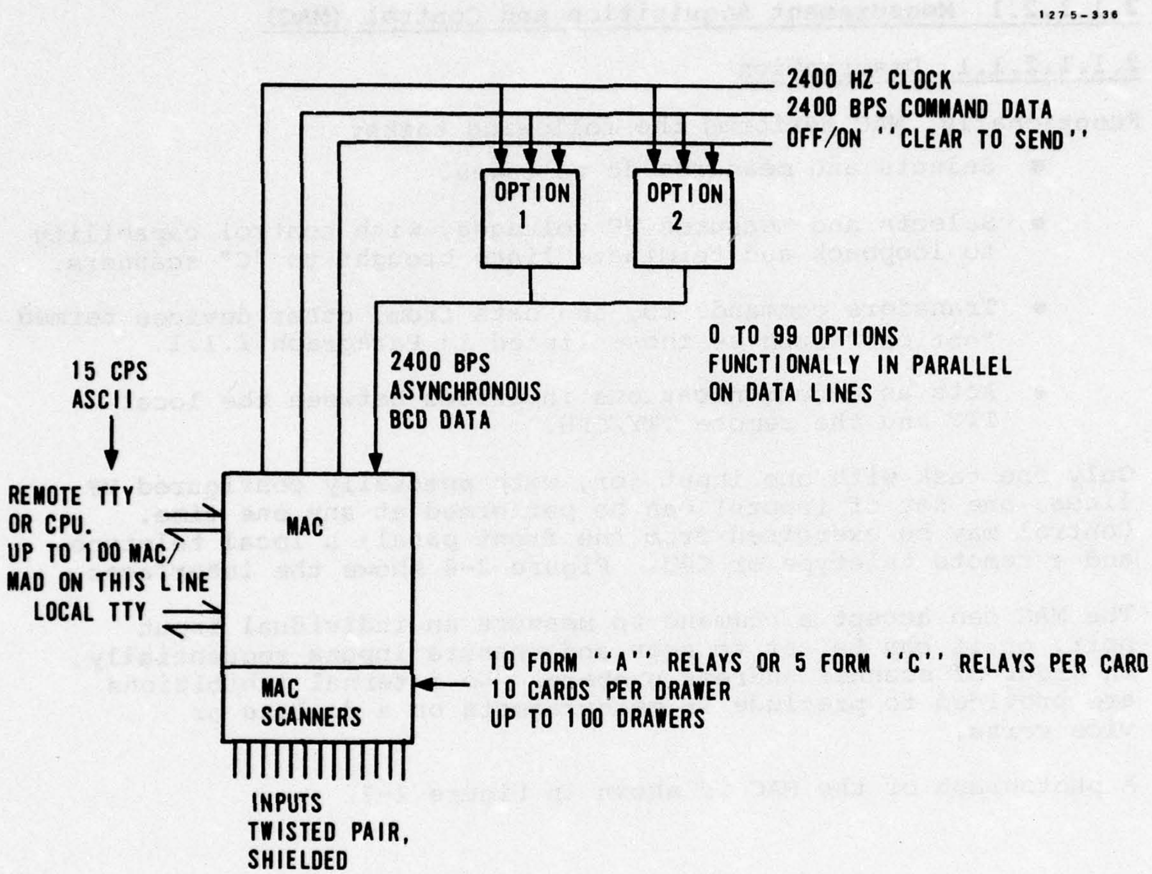


FIGURE 2-6. MAC INTERFACES

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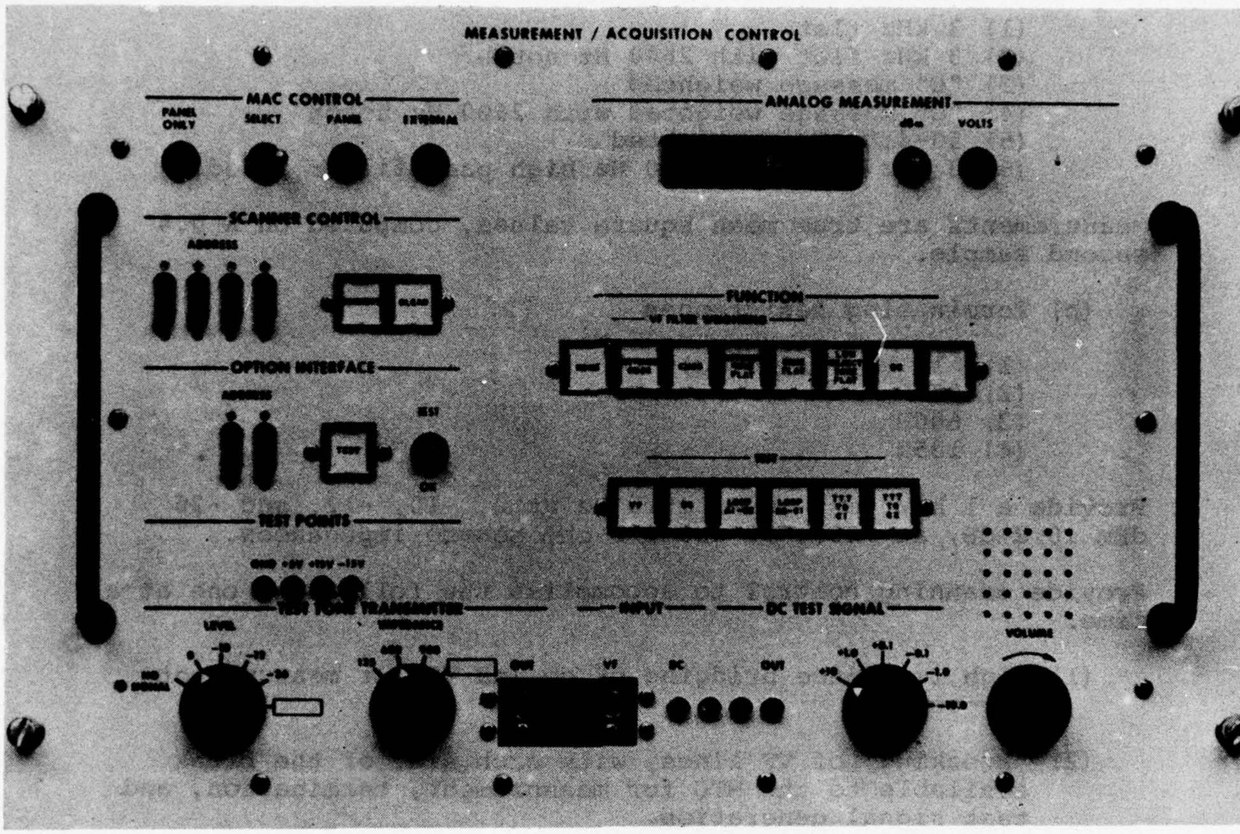

FIGURE 2-7. MEASUREMENT AND ACQUISITION CONTROL

(a) Filter characteristics

(1) 3 kHz flat
(2) 3 kHz flat with 2600 Hz notch
(3) "C" message weighted
(4) "C" message weighted with 2600 Hz notch
(5) 50-4100 Hz unweighted
(6) 3 kHz flat with 200 Hz high pass filter added.

Measurements are true mean square values, computed on a 0.4 second sample.

(b) Terminating Resistances

(1) >10 kΩ (bridging)
(2) 900Ω
(3) 600Ω
(4) 135Ω

- Provide a 1 kHz test tone, ±0.5 Hz at 0, -10, -12, and -26 dBm ±0.2 dB, at 900, 600 and 135 ohm source impedances.

- Provide scanning control to accomplish the following, one at a time.

(1) High impedance bridging of dc and VF for measurement purposes.

(2) "Breaking" of VF lines, with each side of the break available to the MTU for measurement, termination, and test signal generation.

(3) Looping back of VF lines

(4) Interconnection of VF lines

- Control, and provide VF interconnections for, the following VF optional extras:

(1) Test Signal Source. This generates tones, modulated by 25 Hz or unmodulated, stepped or singly at 100 Hz increments in the VF band.

(2) Idle Line Seizure Unit

The functional uses of the VF monitoring and control capabilities are:

(1) In-service functions. These are ingested through form "A" scanners, and do not interfere with nor degrade communications. Monitor functions include:

(a) Channel level, through any of the filter combinations available.

(b) Idle channel noise, with or without the presence of a 2600 Hz supervisory tone.

(c) Supervisory tone level

(d) Idle channel detection

(2) Out-of-service functions of the basic MAC. These are handled through form "A" and form "C" scanners. They intrude upon communications, and require a cooperative device at the other end of the segment of line under test. For each function, both the segment of line under test and the interrupted portion are terminated in their nominal characteristic impedance. Functions included are as follows:

(a) As a receiving device:

(1) Idle channel noise, with any of three filter weightings.

(2) Net loss

(b) As a transmitting device:

(1) Provide a 1 kHz test tone of known level, for measurement of transmission properties.

(2) Provide a source termination, for measurement of idle channel properties.

(c) As a switching device:

(1) Loopback a line upon itself for measurement at the other end of the segment under test.

(2) Interconnect two lines, as for example, testing a line at a distant point through a calibrated reference line.

(3) Out-of-Service Functions of the TSS Option.

The TSS option provides a signal into a communications line which is used by a PATE at the other end for frequency response and envelope delay measurements.

(4) Functions of the ILSC Option:

The Idle Line Seizure Controller (ILSC) determines the VF channel idle/busy status and seizes idle channels for channel testing. ILSC utilization is on interswitch Autovon trunks and subscriber lines with 2600 Hz SF (single frequency) signaling. The ISLC has three major operating modes:

(a) Bridge-on detection mode - determines the Tx and associated Rx line idle/busy status.

(b) Transparency seizure with replacement of the 2600 Hz SF signal during idle periods. The seizure and SF replacements occur on both transmit and receive lines. The ILSC monitors both lines before the seizure point to determine when a call for service occurs. A call for service causes the ILSC at the seizure end to restore the line for normal usage independent of the measurement status. Since there is no communication necessary between the seizure point and measurement end, the restoring time is less than 50 milliseconds, the time of detecting a call for service and reed relay switching.

(c) Conditional seizure mode - identical to the transparent seizure except service is not restored until testing is complete. The conditional seizure mode is utilized to provide a two-point seizure for out-of-service testing.

2.1.1.2.1.3 DC Measurement Capabilities

The dc measuring device used in the MAC has the following characteristics:

Range: ±10 volts, autoranging in internal scales of 0.1, 1.0, and 10 volts.

Accuracy: ±1 percent of measured voltage or ±1 millivolts, whichever is greater.

Input Impedance: 2 megohms or greater

Input Resistance to Ground: 4.7 megohms

Inputs are through the form "A" scanner cards, one at a time.

The dc monitor points, which are brought in through form "A" scanners, have the following uses:

(1) Measurement of communications performance related voltages derived from test points on the communications equipment. Examples are AGC voltage as an indicator of receive signal level; transmitter crystal probe current as a measure of transmitted power; discriminator voltage as a measure of frequency misalignment between transmitter and receiver.

(2) Measurement of equipment and station "general health" related voltages. These quantities cannot be directly related to system performance, but have a nominal value outside of which system reliability may be compromised. Examples are fuel tank levels from electrical sources; power supply voltages, and ambient temperature.

(3) Measurement of performance related voltages derived from the MTU options.

(4) Monitoring of alarms at small sites where installation of a separate alarm scanner is not justified.

The timing of individual measurements varies due to the following factors:

(1) The number of characters in the reply message can vary.

(2) The internal timing and autoranging will vary from measurement to measurement.

In the dc mode, the time required to receive a command, measure a dc voltage, and transmit the voltage to the CPU is 3.1 and 4.2 seconds based on the present MAC hardware design. 3.1 seconds are required to receive the command, measure the voltage once the AGC is set, and send the result to the CPU. AGC

setting time is between 0 and 1.2 seconds depending on how far the AGC must range for the given input signal voltage level. If all input signal voltage levels are alike, the AGC setting time is uniform from 0 to 1.2 seconds and the total measurement time is given by a uniform density function from 3.1 to 4.3 seconds. The mean value of this density is 3.7 seconds which may be regarded as the mean time to measure a dc voltage.

In the sequential scan mode, data from one voltage measurement is being transmitted while the succeeding voltage measurement is being made. This reduces the measurement time excluding AGC setting time to 1.9 seconds and the total time is given by a uniform density from 1.9 to 3.1 seconds. The mean time to collect a dc voltage is the mean of the density which is 2.5 seconds. The data line format is shown in Figure 2-8.

2.1.1.2.1.4 Use with MAC Options

The MAC can control and accept data from options via the types of data lines shown in Figure 2-6. The options are functionally in parallel, and up to 99 options may be controlled by one MAC.

The sequence of data interchange between the CPU and the option, via the MAC, is shown in Figure 2-9, which should be used as a reference during the following discussion.

For addressing an option, the MAC numeric address is followed by a one or two character numeric address denoting the option to which data transfer is intended. All commands to the MAC itself use a nonnumeric following the MAC address; thus the presence of a number in this slot denotes a message to an option. This number is stored in the MAC.

Following the option address are one to sixteen characters of instructions to the option. The MAC stores these instructions internally. It does not transmit to the option until the execute command (G) is decoded in the MAC.

Upon receipt of the "execute" the MAC transmits data to the option. The 2400 Hz clock line is activated, and the data characters are transferred on the data line. Each data character, as transferred to the option, consists of the following elements:

(1) The option address, in BCD.

(2) The seven information bits contained in the ASCII character transmitted to the MAC.

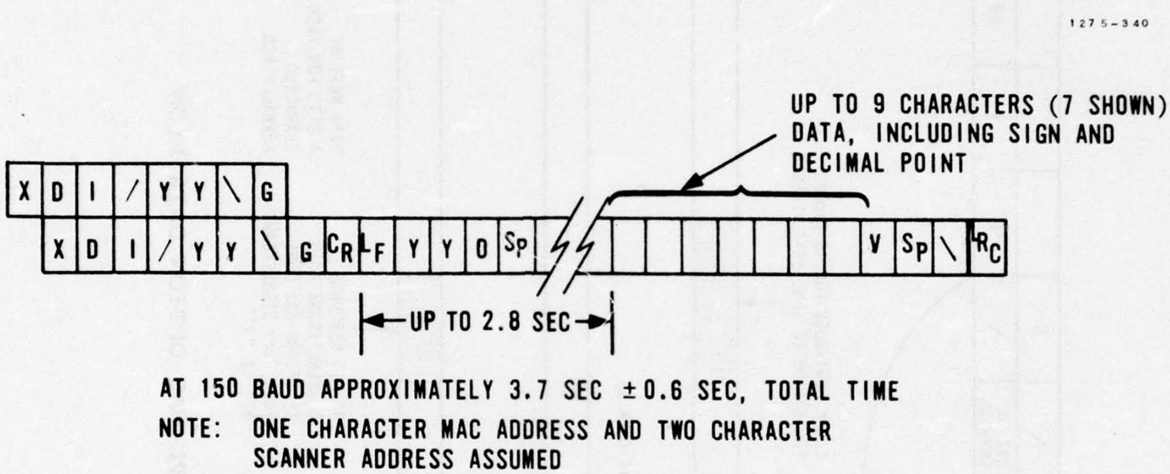

FIGURE 2-8. MAC DATA LINE TIMING - DC

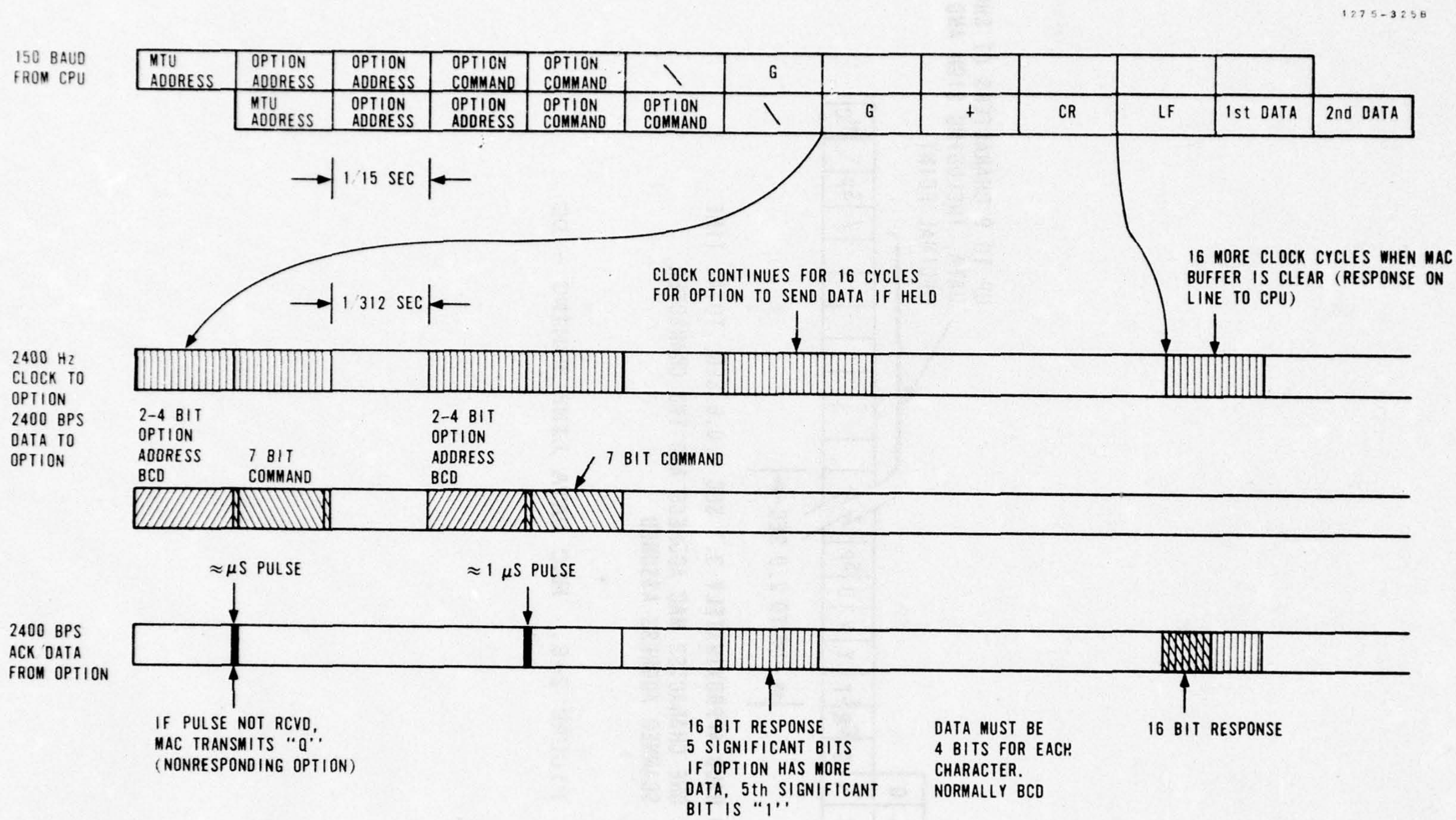

FIGURE 2-9. CPU-MAC OPTION DATA FLOW

Each time the option recognizes its address, it sends a pulse on the return data line. If this pulse is not sensed, the MAC sends a character (Q) to the CPU, denoting a nonresponding option.

At the end of the message to the option, the MAC sends 16 more clock pulses to the option. If the option holds a message to be returned to the CPU, transmission of the first character occurs during this period. Data from an option is in four bit groups, normally BCD.

The form of data from the option is the four bits of BCD plus a fifth bit position, in which a "1" indicates that option has more data to follow. The MAC stores the data, packs the proper bits around the data to form the equivalent ASCII character, and outputs this character on the 15 CPS line to the CPU. When the MAC's memory is cleared, and if the fifth bit indicated that more data follows, another 16 clock pulses are sent, and the cycle repeats itself.

2.1.1.2.1.5 MAC Applicability to Digital System Monitoring

Insofar as slowly varying dc voltages relevant to transmission system monitoring are developed, the MAC may be used as a measuring and telemetering device. Volume I has identified the requirements for this type of measurement of voltages directly derived from the system.

Digital systems monitoring has the requirement for measuring events per unit time and whether or not an event has occurred in a certain interval. These quantities are convertible to dc voltages which can be handled by the MAC as any other dc voltages.

The baseband monitor is described in Paragraph 2.1.7. Means of adapting the monitor to assess performance margin of the digital baseband are described in Paragraph 3.2.2. This adaption requires a control input to set the monitor input, sensing device to measure its outputs, and the capability of telemetering data to the data processing device. The option control capability can provide the instructions to the device, while either the option return data line or the dc voltmeter are available for accepting returned data for forwarding to the processor.

The MAC is potentially useful for VF measurements of channels traversing digital transmission paths, within the limits of its capabilities. Idle channel noise and gain may be measured directly.

In-service measurements of signal to distortion ratio on idle channels with 2600 Hz supervision can be performed. The interpretations and ambiguities of these measurements are discussed in the I/OQCS applicability portion of this report, Paragraph 2.1.3.2.

2.1.1.2.2 Analog Scanners

2.1.1.2.2.1 Description

The scanner is a random access switching unit which connects the monitored point to the measuring device used. At present the IQCS, I/OQCS, DDMS, and MAC are capable of controlling scanners. In theory, up to 10,000 points may be controlled by a single device. A scanner drawer is portrayed in Figure 2-10.

Two types of scanners are used. One is the simple, bridge-on form "A" scanner, which places the monitoring device effectively in parallel with the monitored point. The other type is a form "C" scanner which breaks the circuit and substitutes the measuring device for the circuit. Inputs to the scanners are through twisted, shielded pair, and each scanner relay switches three wires. See Figures 2-11A and 2-11B.

Four buses are used to route signals from the addressed relays to the measuring device. These are termed C_T (form C, transmit); C_R (form C, receive); A_T (form A, transmit); and A_R (form A, receive). For the bridging application, it is immaterial which of the A buses is used.

For out-of-service VF testing, the scanners are configured in the particular manner shown in Figure 2-11C. In this configuration the measuring device terminates and measures the incoming line through the "A" buses while providing a signal and/or source termination through the "C" bus.

Unaddressed scanner cards and chassis are disconnected from the bus in order to maintain low bus capacitance.

Scanners are selected by a 16 bit BCD serial code, with one digit each for rack, drawer, card, and relay. For normal, in-service

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FIGURE 2-10. ANALOG SCANNER

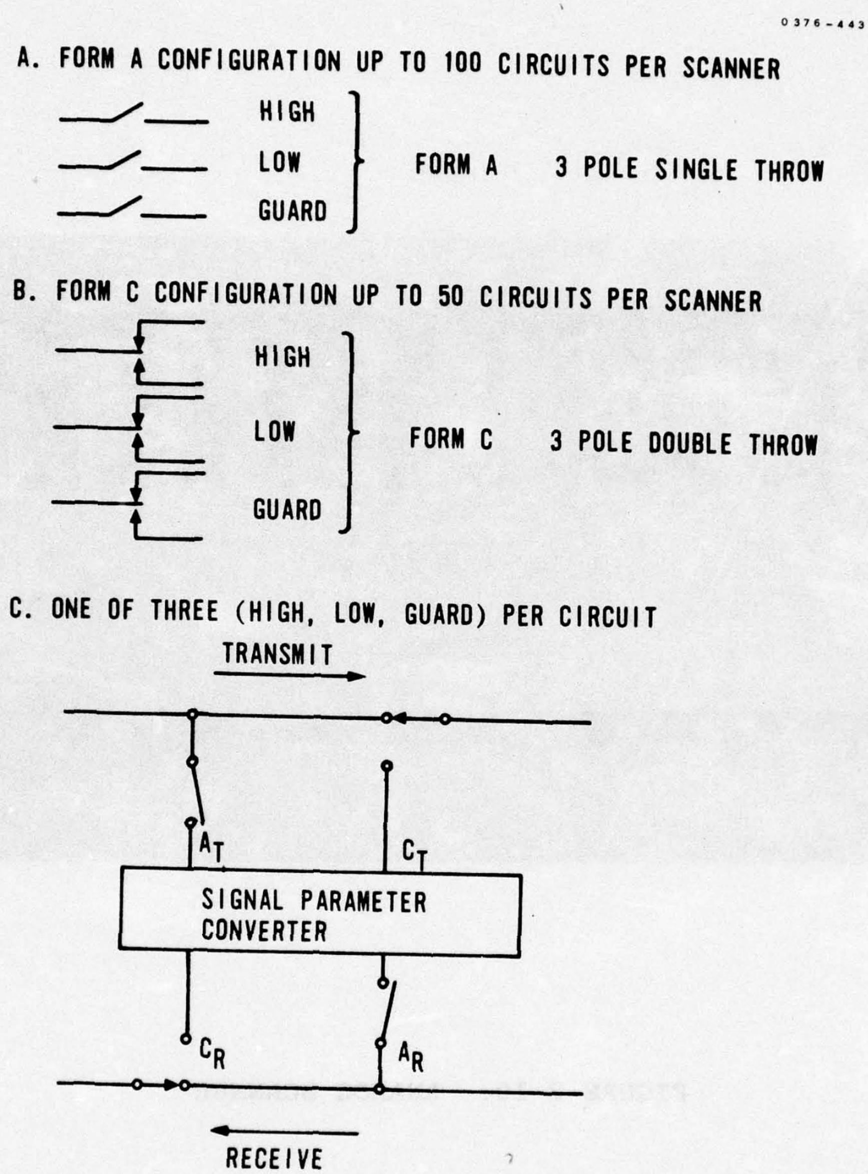

FIGURE 2-11. SCANNER RELAY CONFIGURATIONS

measurements, only one form "A" scanner is selected at a time. For out-of-service testing, two form "A" and two form "C" relays may be selected.

2.1.1.2.2.2 Analog Scanner Applicability to Monitoring Digital Systems - Unmodified

To the extent that digital systems generate analog voltages, which should be monitored by an ATEC system element, the analog scanner is required to bring the signal to a measurement device. Volume I has identified sixteen analog parameters per radio set; nine per higher level (T1-4000) multiplexer, and seven per lower level (T1WB1) multiplexer for analog measurement.

Systems with voice frequency inputs and outputs require some VF monitoring capability for quality control checking, and, in hybrid systems, for separation of problems between the analog and digital networks. The analog scanners are well suited to performing the VF function.

2.1.1.2.2.3 Analog Scanner Applicability to Monitoring Digital Digital Systems - With Adaptations

Monitoring of digital systems requires latching the fact of existence of events, and requires determination of the rate at which events are occurring. The present ATEC system has this capability only in the impulse noise counter of the I/OQCS, which can be used on only one input at any one time.

The analog scanner is a viable candidate for incorporation of this capability because it is more economical than expanding the I/OQCS impulse noise counter. Use of the analog scanner would reduce the number of focal points to which monitored points must be attached and the modules required can be fitted into the physical configuration of the analog scanner card. By using a scheme in which the output is in the form of dc voltages, the existing measurement and telemetry capability of the MAC can be utilized without modification.

The adaptation of the scanner to these functions is considered in more detail in Paragraph 3.1.1 of Volume II of this report.

2.1.2 Baseband Signal Analyzer (BBSA)

2.1.2.1 Description

The Baseband Signal Analyzer (BBSA) is a computer controlled automatic signal level measuring equipment used to measure the root mean square (rms) values of signals, in the frequency

range of 12 kHz to 5 MHz, utilized as basebands for frequency division multiplex (FDM) equipment. It performs automatic scan measurements of the following signal types:

a. Channel

b. Group

c. Interchannel

d. Out-of-Band

e. Pilot

f. Carrier

g. 2600 Hz Idle Tone

It compares the measured level with specified thresholds and for measurements which exceed the threshold reports the level value and frequency identification. The BBSA performs a Fast Fourier Transform (FFT) on translated channels (0-4 kHz) and displays the frequency spectrum on a standard oscilloscope at remote distances up to 500 feet. The BBSA contains circuitry for self-test.

Single frequency test tones are generated in the Baseband Signal Injector, a part of the BBSA, for bridge-on injection into in-service basebands. Both the desired signal level and frequency are under computer control.

Leading particulars, capabilities, and limitations for the BBSA are given in Tables 2-2 and 2-3. Table 2-4 tabulates the BBSA measurement modes.

2.1.2.2 BBSA Applicability to Digital System Monitoring

The BBSA was specifically designed to measure the signal characteristics of supergroups, groups, and channels within a frequency division multiplex (FDM) baseband. It is an important performance assessment tool in an analog/FDM transmission system, but it has little or no application in the performance assessment of digital transmission systems.

2.1.3 In-Service/Out-of-Service Quality Control Set (I/OQCS)

2.1.3.1 Description

The In-Service/Out-of-Service Quality Control Subsystem (I/OQCS) is a computer-controlled automatic test system designed to perform

TABLE 2-2. BBSA LEADING PARTICULARS

Operating Characteristics	Description
Baseband Coupler	
Frequency	12 kHz to 5 MHz
Insertion Loss	0.1 dbm (nominal)
Response	±0.25 dbm
VSWR	1.1:1
Impedance	
Input	75 ohms
Output	50 ohms
Coupling Level (Passive)	-17 db (nominal)
Coupling Level (Active)	+20 db (nominal)
Scanner	
Frequency	12 kHz to 5 MHz
Input Level	-130 dbm to +20 dbm
Response	±0.25 db
Insertion Loss	0.1 db (maximum)
Input Impedance	50 ohms ±10 percent
Frequency Synthesizer	
Range	1 MHz to 160 MHz
Output Level	+3 dbm to +13 dbm into 50 ohms
Accuracy	±1 db over frequency
Spurious Response	
Harmonic	25 db below fundamental
Non-Harmonic	100 db below fundamental

TABLE 2-3. BBSA CAPABILITIES AND LIMITATIONS

Operating Characteristics	Description
Baseband Signal Converter	
Frequency	
Range	12 kHz to 5 MHz
Amplitude	-9 dbm to -45 dbm ±0.25 (60 kHz - 2.5 MHz) ±0.5 (12-60 kHz, 2.5-5 MHz)
Stability	±2 parts x 10^{-9}/24 hours as a function of ambient temperature (1×10^{-8} from -5°C to +55°C)
Selectivity	3 db rejection at:
(Generated by FFT)-----	48 kHz BW - 48 kHz (minimum) 3100 Hz BW - 3100 Hz (minimum) 100 Hz BW - 100 Hz (minimum) 16 Hz BW - 16 Hz (minimum)
	60 db rejection at:
(Generated by FFT)-----	48 kHz BW - 50 kHz (maximum) 3100 Hz BW - 4 kHz (maximum) 100 Hz BW - 400 Hz (maximum) 16 Hz BW - 120 Hz (maximum)
Spurious Response	
Single/Pair Test Tone(s)	Not greater than -60 db with respect to test tone level within the measured channel
Remote Control	
Input	Asynchronous, 150 baud
Code	USASCII
Internal-Standard	5 MHz ±1 parts x 10^{-9}/24 hours
Temperature Stability	1×10^{-8} from -5°C to +55°C
Auxiliary Output	5 MHz at +13 dbm
Baseband Signal Injector	
Frequency	
Range	12 kHz to 5 MHz
Stability	Same as Frequency Synthesizer
Output Level	-10 dbm to -60 dbm ±0.25 db (60 kHz - 2.5 MHz) ±0.5 db (12-60 kHz, 2.5-5 MHz) into 75 ohms through passive Baseband Coupler

TABLE 2-4. BBSA MEASUREMENT MODES

1. Baseband	Measures composite rms signal level of the selected baseband. The bandwidth is 12 kHz - 5 MHz.
2. Group	Measures rms signal level of group bandwidths (48 kHz). Automatic scan of up to 51 groups is provided by identification of start and stop group numbers in the measurement command.
3. Channel	Measures rms signal level of channel bandwidths (3.1 kHz). Automatic scan of up to 612 channels is provided by identification of start and stop channel numbers in the measurement command.
4. 2600 Hz	Measures rms signal level of 2600 Hz tones. An FFT analysis of the channel bandwidth compares signal energy at 2600 Hz to that present in the remainder of the channel and computes the S/N ratio. The frequency and level value is outputted when a S/N ratio of greater than 30 db is obtained. Automatic scan of up to 612 channels is provided by identification of start and stop channel numbers as part of the measurement command.
5. Interchannel	Measures rms signal level between channels. The 3.1 kHz channel filter center frequency is placed at the channel carrier frequency. An FFT analysis of the channel bandwidth is performed and the rms level value from the eight 100 Hz filter values around the carrier is computed. Automatic scan of up to 612 channels is provided by identification of the start and stop channel numbers as part of the measurement command.
6. Out of Band	The rms signal level of five channel bandwidths is automatically scanned and measured when an Out of Band measurement command is given. The frequency values for the channels are contained in the data base.
7. Carrier	Measures rms signal level value of the channel carrier using the 16 Hz bandwidth filter. Automatic scan of up to 612 carriers is provided by identification of the start and stop channel carrier numbers as part of the measurement command.
8. Group Pilot	The rms signal level of the group pilot is measured using the 16 Hz bandwidth filter. Automatic scan of up to 51 groups is provided by identification of the start and stop group numbers as part of the measurement command.

in-service and out-of-service monitoring, alarm reporting, and trend analysis on voice frequency (VF) communications circuits. The IQCS (In-Service Quality Control Subsystem) section of the I/OQCS is used within the Technical Control Facility to provide performance monitoring of active communications circuits without interrupting normal traffic flow. The OQCS (Out-of-Service Quality Control Subsystem) section of the I/OQCS provides additional performance monitoring capabilities with the communication circuit interrupted (usually an idle line). The I/OQCS may be controlled locally or remotely. Local control is furnished by Teletype Set, ASR-37. Remote control of the I/OQCS is accomplished through the CPMAS Nucleus System. The choice of local or remote control is selected at the I/OQCS position.

The I/OQCS is mounted in a standard 19-inch electronic equipment rack and may contain as many as four form A or form A and C scanner drawers. Each form A or C scanner is capable of monitoring 15 full duplex circuits and 10 additional bridge only circuits. Control of the scan sequence is provided by the program loaded in the Honeywell 316R computer. The derived data of each scan is measured by the Signal Parameter Converter and processed by the computer. The results of the data processing are presented to the Technical Controller as a hard copy printout on the teletype printer. The teletype set may be used to interrupt the normal program sequence when specific data for any circuit or combination of circuits is desired by the local Technical Controller.

The I/OQCS has the ability to make measurements in conjunction with the Idle Line Seizure Controller (ILSC) and the Monitor Telemetering Set (MTS) when the CPMAS (Communications Performance Monitoring-Assessment System) appropriately controls these units. The I/OQCS provides a comparison of parameter measurements to known/predetermined thresholds and provides alarm conditions based on this comparison.

The IQCS uses the measured amplitude samples to perform the following computations:

a. SF_i = Spectrum filter value (dbm) of the ith filter, i = 1-40 corresponding to 100 to 400 Hz.

b. I1 = Minimum 10 ms average power (dbm)

c. X1 = Maximum 10 ms average power (dbm)

d. X5 = Maximum 50 ms average power (dbm)

e. I5 = Minimum 50 ms average power (dbm)

f. VU = Volume units (VU)

g. AV = Average power (dbm)

h. PI = Peak signal power (dbm)

i. PA = Peak to average power (db)

j. P1 = Maximum 10 ms to average power ratio (db)

k. P5 = Maximum 50 ms to average power ratio (db)

l. M1 = Maximum 50 ms to minimum 10 ms power ratio (db)

m. M5 = Maximum 50 ms to minimum 50 ms power ratio (db)

n. WN = Weighted noise, C MSG* (dbm)

o. SN = Signal to noise* (db)

p. NC = Noise coloration* (db)

q. FR = Noise frequency* (Hz)

r. HD = Harmonic distortion* (db)

s. SM = Spectral moment (Hz)

t. SW = Spectral width (Hz)

u. AF = Area factor

v. NW = Spectral noise bandwidth (Hz)

w. WF = Weighted noise, 3 kHz flat* (dbm)

x. FN = Unweighted noise* (dbm)

y. VN = VU to I5 ratio (db)

z. R1 = Spectrum ratio 1 (db)

aa. R2 = Spectrum ratio 2 (db)

bb. R3 = Spectrum ratio 3 (db)

cc. R4 = Spectrum ratio 4 (db)

dd. FR = Frequency (Hz)

* Calculations dependent upon traffic type.

Definition of terms used in relationship to the IQCS:

a. Noise frequency (NF) - Maximum spectrum filter value (SF_i) on an idle and test tone channel (after test tone removal).

b. Noise coloration (NC) - Relative energy at NF compared to adjacent SF_i's.

c. Area factor (AF) - A value relating the area of the signal spectrum plot from 300 to 3000 Hz to the area of a plot in which all values from 300 to 3000 are equal to the measured maximum value.

$$AF = \frac{28 \times \text{Maximum Value}}{\text{Area of Signal Spectrum}}$$

d. Spectrum ratio (R_n) - There are four sets of numerator and denominator spectrum ratio words, each word consisting of 40 bits. These bits represent the filter outputs of the FFT. If a bit is one, it means that particular filter is to be included in the summation. Spectrum ratio 1 (R1) is the summation of all the filters indicated by the numerator word divided by the summation of the filters indicated by the denominator word. R2, R3, and R4 are computed in the same manner.

$$R_n = 10 \log \frac{\Sigma SF_i R_{Nni}}{\Sigma SF_i R_{Dni}}$$

where

n = spectrum ratio (1-4)

i = filter number (1-40)

N = numerator

D = denominator

e. Spectrum moment - A measure of the average frequency using all values of SF_i's.

f. Spectrum width - A measure of spectrum width about the spectral moment.

g. Spectrum noise bandwidth - A measure of the spectrum width using SF outputs from 300 to 3000 Hz.

The IQCS section provides parameter interpretation as follows:

a. Spectral composition ratio. Up to four spectral composition ratios can be specified, selected, and computed.

b. Traffic recognition

1. Voice
2. Wide spectrum, high crest factor
3. Wide spectrum, low crest factor
4. Narrow spectrum, high crest factor
5. Narrow spectrum, low crest factor
6. Test tone
7. Supervisory tone (2600 Hz)
8. Idle Channel
    a. Level of assigned tone, if present
    b. Signal-to-noise ratio from assigned tone

c. Noise weighting functions

1. 3 kHz flat weighting characteristic
2. C-Message weighting characteristic
3. Unweighted. 100 to 4000 Hz spectrum values unweighted.

The OQCS section of the I/OQCS is capable of performing those tests and analyses of lines which cannot be performed while in-service, by automatically removing the line from service at the bridge/break point and performing appropriate operation.

The OQCS section is capable of making the following measurements in conjunction with the Test Signal Source:

a. Measurements on a test tone transmission at 1 kHz as follows:

1. Averaging time: 2 seconds, minimum
2. Loss: -10 db to +60 db total range
   0 db to +30 db accuracy
3. Test tone to noise ratio: 0 to 45 ±0.5 db, tone present, C-Message weighted or 3 kHz flat weighted noise.
4. Frequency offset: ±500 Hz relative to 1 kHz, nominal ±0.1 Hz accuracy
5. Phase jitter measurement:

   Range: 0 to 45° peak-to-peak jitter

   Accuracy: ±1.0 degrees for input signal levels from -40 dbm and rates from 0 to 300 Hz

6. Phase hits - A phase hit occurs whenever a phase change on a nominal 1 kHz test tone exceeds the hit threshold degree. The hit threshold is adjustable in one degree steps over a range of 0 to 45 degrees.

7. Amplitude hits - An amplitude hit occurs whenever the amplitude of a 1 kHz signal exceeds the threshold L_H. Thresholds are adjustable in 1 db steps from -60 to +10 dbm.

8. Dropouts - A dropout occurs whenever the amplitude drops below a threshold L_L for a specified length of time. Dropout threshold is adjustable in 1 db steps from -60 to +10 dbm.

9. Harmonic distortion - This is a measure of the relative magnitude of the fundamental frequency and the second and third harmonics. Accuracy is ±1.0 db for harmonics between 0 and -50 db relative to the fundamental and greater than -70 dbm.

b. Measurements on a line having an input test signal of a 0 dbm sinewave, frequency stepped in 100 Hz increments from 200 Hz to 3600 Hz with 50 percent, 25 Hz Amplitude Modulation (AM) is as follows:

1. Measurement duration: 15 seconds for entire band, 200 Hz to 3600 Hz.

2. Amplitude response (loss): -10 db to +60 db over stepped frequency range. Accuracy overstepped frequency range 0 db to +30 db ±0.25 db.

3. Envelope delay response: ±20 millesecond range between adjacent 100 Hz center frequencies.

   ±20 millesecond range from 200 Hz to 3600 Hz.

   ±20 microsecond (μs) accuracy over frequency range 600 Hz to 2700 Hz.

   ±40 microsecond (μs) accuracy over frequency range 200 Hz to 3600 Hz.

c. Intermodulation distortion measurements are made on a two tone signal (tones at 700 Hz and 1100 Hz). Intermodulation distortion products are measured with ±1 db accuracy if they are above -45 dbm and stronger than -40 db relative to the average power of the 700 Hz and 1100 Hz tone. The intermodulation products of interest fall at the following frequencies:

   $f_1 + f_2$ = 1800 Hz, second order

   $2f_1 + f_2$ = 2500 Hz, third order

   $-f_1 + 3f_2$ = 2600 Hz, fourth order

d. Measurements made on an idle channel with no intentional signals present other than possible interference are:

   1. Averaging time: 2 seconds nominal

   2. Spectrum measurement:

      Level range: -60 dbm to +10 dbm

      Frequency: 100 Hz to 4000 Hz

      Frequency increments: 100 Hz

   3. Spectrum measurement bandwidth per 100 Hz increment: 150 Hz nominal.

   4. Spectrum measurement accuracy per frequency increment: +0.1 db provided that no band is 10 db higher than any other.

   5. Spectrum processing: tone interference (or signal) is noted if a frequency increment level is greater by 6 db than adjacent increments. The noise frequency is noted together with the level in dbm. C-Message noise, 3 kHz flat, and 3 kHz flat minus C-Message noise are calculated to ±0.5 db accuracy.

   6. Impulse noise measurement: impulse noise measurement is selectable. The OQCS section detects and counts all events which occur during the test period above the three thresholds of L_1, L_2, L_3 dbm, as preset.

A summary of I/OQCS capabilities and limitations is contained in Table 2-5.

2.1.3.2 I/OQCS Applicability to Digital System Monitoring

2.1.3.2.1 Digital Systems-Related Properties

As can be seen, the I/OQCS measurement capabilities include: average power, peak power, VU, loss, noise, power spectra, frequency accuracy and stability, phase jitter, harmonic and intermodulation distortion, envelope delay, amplitude response, and impulse noise counts.

TABLE 2-5. I/OΩCS CAPABILITIES AND LIMITATIONS

Characteristics	Description
System Input	
Frequency	100 Hz to 4.1 kHz
Range	+20 dbm to -70 dbm
Attenuation	0 to 90 dbm in 6 db steps
Maximum Input Amplitude	30 volts pk-pk
Input Impedance	
Terminating	135, 600, 900 ohms plus one selectable
Bridging	>10 k-ohm dc, >10 k-ohm ac
Circuit Capacity	15 full duplex and 10 bridge only per scanner
Basic Measurement Accuracy	
Average Power	+10 dbm to -60 dbm ± 0.2 db
Peak Power	+10 dbm to -60 dbm ± 0.2 db
Signal Spectral Composition	±1 db in 100 Hz increments from 100 to 4000 Hz
Derived Measurement Accuracy	
Noise (C-Message)	±1.5 db for noise >-70 dbm
Frequency	±1 Hz from 250 to 3850 Hz
Harmonic Distortion	±1 db for harmonics between 0 and -50 db relative to fundamental and >-70 dbm
Signal to Noise Ratio	±1.5 db when signal to noise is 20 db or greater

The I/OQCS is applicable to digital system monitoring through its ability to totally characterize the performance characteristics of VF circuits. It may provide pertinent performance assessment information by evaluating the VF circuits prior to PCM encoding and after PCM decoding to detect signal degradation resulting from equipment malfunction during the encoding/decoding or transmission process. Signal characteristics measured at the channel output from the CY-104 provide important data for use in fault isolation algorithms. VF channel parameters of particular interest in digital transmission systems are impulse noise counts, phase jitter, and noise (quantizing).

IQCS measurement capabilities include: average power, peak power, VU, noise, power spectra, and harmonic distortion.

The IQCS is applicable to digital system monitoring through its ability to characterize in-service VF circuits. It may provide pertinent information by evaluating VF circuits prior to PCM encoding and after PCM decoding to detect signal degradation resulting from equipment malfunction during the encoding/decoding or transmission process. Signal characteristics measured at the channel output from the CY-104 provide important data for use in fault isolation algorithms. In-service VF channel parameters of particular interest in digital transmission systems are noise (quantizing) and average power level.

2.1.3.2.2 Inferring Digital Transmission Aberrations

Volume II, Appendix B, of this report analyzes the subject of inferring digital transmission system errors from measurements of analog parameters. It is shown that impulse noise counts can be related to digital error rates on all digital transmission systems. If the I/OQCS impulse counter is manually jacked into the line under test, counting can be done without interfering with other operations. See Appendix B for an indepth discussion of this subject.

2.1.3.2.3 Monitoring of Hybrid Circuits

Regardless of the nature of the transmission system at any given TCF, that TCF is responsible for the quality of service provided users of that facility. The serving TCF is responsible for scheduled end-to-end quality control checks on the entire circuit, and for initiating corrective measures if service is degraded.

As long as analog transmission systems are in substantial use, therefore, the capability of measuring the types of degradation introduced by analog, as well as digital, systems is required. Possession of a full capability enhances degradation isolation capability. As examples, moderate or severe phase jitter in a hybrid system must originate in the analog system, while strongly level dependent noise is probably caused by the elements associated with the PCM portion of the system.

2.1.4 Modem Signal Monitoring Subsystem (MSMS)

2.1.4.1 Function

The MSMS, as an optional subsystem of the IQCS or I/OQCS, provides non-interfering, in-service, monitoring of Frequency Shift Keyed (FSK) subchannels of voice frequency carrier telegraph (VFCT) frequency division multiplexed tone packages, to permit assessment of quality and performance. VF signals from IQCS or I/OQCS are directed to the MSMS hardware functions for preliminary processing. The preliminary processing includes FSK subchannel extraction and demodulation for analog and digital processing by the IQCS or I/OQCS.

2.1.4.2 MSMS Applicability to Digital System Monitoring

The MSMS is very specifically intended for monitoring the individual subchannels of an FSK composite tone package. As such, it has no particular relevance to digital system monitoring.

Whenever tone packages traverse the digital system to a user served by a TCF on that system, the MSMS may be used to monitor service to and from the user, and can assist in locating the probable source of some problems. In this application, its use is analagous to that of the I/OQCS, described in Paragraph 2.1.3.

2.1.5 Digital Distortion Monitoring Set (DDMS)

2.1.5.1 Description

The Digital Distortion Monitoring Subsystem (DDMS) is a computer controlled automatic test and evaluation system which performs in-service monitoring, alarm sensing, and trend analysis of digital data signals. The DDMS can measure and evaluate asynchronous data from 25 to 10,000 baud and synchronous data from 50 to 10,000 baud. The system is controlled by a Honeywell 316R computer. Local control is available as

a program interrupt, through use of a teletype such as the ASR-37 or equivalent. The DDMS is used by Technical Control Facility (TCF) personnel to obtain performance checks of active digital data circuits without interruption of normal traffic flow. In operation the DDMS automatically selects a data circuit, samples and stores data proportionally to the time interval of the signal elements, computes the distortion parameters, compares the computation to stored alarm limits, and flags those parameters which are out of tolerance. In addition, the calculations are analyzed for trend indications, (improving, degrading or stable) and transfers all the measured and calculated data to the readout device, Teletype Set ASR-37, automatically, if programmed, or upon operator command. Computation on monitored data includes, but is not limited to measurements of digital distortion, range error, operating margin, bias distortion, and fortuitous (chance) distortion.

DDMS capabilities and limitations are summarized in Table 2-6. A listing of DDMS measurements is given in Table 2-7.

2.1.5.2 DDMS Applicability to Digital System Monitoring

The DDMS is a device for measuring the digital distortion on low speed synchronous and asynchronous two state digital data lines. As such, it is usable, without modifications, for monitoring the low speed inputs and outputs from the CY-104 multiplexer.

With modifications to both hardware and software, and some loss of accuracy, the DDMS can be modified to accommodate higher data rates up to 50 kilobits per second, the rate employed with the T1WB1 in the FKV.

In analysis of the FKV network, it was determined that the high rate (50 Kb/s) digital circuits were either terminated in-station or were interconnected with a group data modem, which is a retiming device. The introduction of significant digital distortion by in-station cabling is improbable. Therefore, adaptation of the DDMS for this application is deemed unrewarding in terms of effectiveness obtained.

TABLE 2-6. DDMS CAPABILITIES AND LIMITATIONS

Characteristics	Description
System Inputs	
Frequency	
Asynchronous	25 to 10,000 Baud
Synchronous	50 to 10,000 Baud
Amplitude	
Maximum	±120V
Impedance	
All Modes	>10KΩ
Measurement Accuracy	
25 to 10,000 Baud	±1 percent

TABLE 2-7. DDMS MEASUREMENTS

Type Measurement	Method
Start Bit Error (SE)	Deviation of measured start bit transition from ideal transition in percent. (Not used in measurements of synchronous data).
Baud Error (BE)	Deviation of measured Baud rate from programmed rate in percent + = high, - = low.
Fortuitous Distortion (FD)	Distortion in percent resulting from random causes such as noise. Has no cyclic pattern.
Composite Distortion (CD)	A percent value resulting from the sum of BD plus the absolute value of FD with the sign of FD the same as BD.
Peak Distortion (PD)	The greatest single value in percent of distortion noted in any of the measurements described above.
Average Operating Margin (AM)	Percent of overall deviation permissible without loss of traffic sense.
Minimum Operating Margin (MM)	Percent of permissible deviation beyond which traffic sense is lost.
Sensitivity 1 (S1)	Bias distortion (BD) measured in percent at slicing level, less the BD measured at slicing level (SL) + sensitivity voltage (ΔV). (BD_{SL} - {(BD_{SL} + ΔV)}).
Sensitivity 2 (S2)	(BD_{SL} - {BD_{SL} - ΔV}) (see Sensitivity 1 above).

2.1.6 Nucleus Subsystem

2.1.6.1 General

The Nucleus Subsystem is a data processing facility composed of the following elements:

a. A central processor with 32,000 words of memory.

b. A data concentrator with 16,000 words of memory.

c. Two disk storage units with 2,480,000 word storage, operated redundantly.

d. One to six consoles, incorporating a CRT display; keyboard entry, and pushbutton function entry.

e. Teletypewriters, as required.

f. A magnetic tape storage unit.

g. Multiline controllers, for up to 64 full duplex data ports.

The Nucleus Subsystem accepts inputs from many ATEC Terminal Equipment (ATE) devices and presents the coordinated results to an operator for further analysis. The ATE provides inputs that are automatically coordinated with other ATEs by the Nucleus; performs tests in concert with other ATEs as commanded by the Nucleus; performs special tests both automatically or on demand to aid in system fault isolation, and provides specially requested data to permit statistical analysis of system problems. Many of the coordinated measurements are made automatically through the specialized system employed in the processing unit. Upon request, monitored results from an ATE are presented to an operator at the Nucleus Technical Control Console for use in directing further performance assessment actions.

The Central Processor (CP)/Data Concentrator (DC) combination is a dual processor configuration, using two Honeywell 316R computers. The DC computer provides the serial-to-parallel and parallel-to-serial data translation required for the Central Processor to communicate with the ATEs. The interface between the Data Concentrator and Central Processor is via a Honeywell standard Intercomputer Communication Unit (ICCU) which permits a high speed data transfer using the Direct Multiplex Control (DMC) option of the H-316R. One of the

basic functions provided by the Nucleus is the data base which associates the ATE "test points" to each other and to the physical organization of the communications network which is monitored. This accessible data base permits the system to coordinate many ATEs and test points for the purpose of rapid fault isolation. This large data base is stored on disks with a second storage facility, magnetic tapes, also provided as part of the Central Processor. Magnetic tape storage is used primarily for recovery in case of disk unit failure. The prime man/machine interface is located at the Technical Control Console and CRT Terminal through the Page Panel Control (PPC). The PPC is a set of illuminated pushbutton switches whose functions are determined by the position of cams, operated by a group of overlay boards with the appropriate functional labels engraved on them. The functions provided by the PPC are listed in Table 2-8.

2.1.6.2 Trouble Tickets and Activity Messages

A considerable portion of the nucleus subsystem capability is devoted to keeping records of communications system problems.

The ATEC system records communication system anomalies in two ways. One is by Trouble Tickets which are manually executed as a result of a user call, monitored thereafter, reported on as required, and accounted for until problem correction. The other is by activity messages, which are generated by the ATEC system.

Use of the RECORD CALL button on the Coordinator's page without an accompanying RECORD NO. entry will cause the associated CRT to display a blank Trouble Ticket (TT) format. The Coordinator then enters the information describing the user's problem.

Upon describing the problem to the extent possible on the TT format, the Coordinator then makes the disposition decisions necessary and dispatches the TT. The TT can be routed to a performance assessment station (Trouble Ticket queue) or directly to a Tech Controller dependent upon the description of the problem. It may also be transmitted to a remote TCF if warranted, or held in the File queue for further investigation later.

Communications system malfunctions and degradations detected through ATEs will cause the appropriate data to be entered into an Activity Message (AM) form. In addition, acquisition of data from disk storage relative to each reported malfunction is made to permit further handling. The resultant statement

TABLE 2-8. PAGE PANEL PUSHBUTTON FUNCTIONS

Page	Label
Coordinating	Record Call
	Record Close
	Assign Acknowledge
	Routing Queue
	File Queue
	Approval Queue
	Record Priority Summary
	Record Assign Summary
	Report Summary
	Routing Queue Summary
	Station Log
Performance Assessment	Record Call
	Service Restored
	Assign Acknowledge
	Trouble Ticket Queue
	Results Queue
	Monitor Immediate Test Selection
	Special Scan Test Selection
	Associative Test Selection
	MTU Scan Test Selection
	Record Priority Summary
	Record Assign Summary
	Results Summary
	Activity Message Queue Summary
	Data Base
	Master Test Directory
	Special Test Directory
	Active Test Directory
	Station Log

TABLE 2-8. PAGE PANEL PUSHBUTTON FUNCTIONS (CONTINUED)

Page	Label
Reporting	Record Call
	Store Log
	DCA Report Queue
	O&M Report Queue
	Wait Queue
	DCA Release
	O&M Release
	Format DCA
	DCA Report Queue Summary
	O&M Report Queue Summary
	Wait Queue Summary
	Record Priority Summary
	Record Assign Summary
	Report Summary
	Station Log
System Control	Display Summary
	Manual Block Summary
	Preventive Maintenance Block Summary
	System Alarms
	Activity Message Queue Format
	Set Block Format
	Load CRT
	Display Management
	Data Base
	Keep Alive Local Alarm
	+5 V A Local Alarm
	+5 V B Local Alarm
	+12 V Local Alarm
	-12 V Local Alarm

of the problem is queued up for inspection and further handling before assignment of responsibility for the problem is made.

Certain tests upon the severity and nature of the problem are first made to determine whether it is best served by ATEC (the Nucleus Subsystem), the originating TCF or some other TCF.

All problem records presented in the system (not closed out) are available for inspection by the use of:

a. Record Call - RECORD CALL may be commanded with the record (Activity Message or Trouble Ticket) number in the window and SEND.

b. Record Priority Summary - Execution of this command causes the Record Summary consisting of open Trouble Tickets and Activity Messages to be displayed on the CRT, ordered by priority. (1-10 as stored in data base for each test point.)

   Any desired record may be selected by placing an "X" in front of it and depressing SEND ALL on CRT keyboard.

   Until Service Restoration entry is made, the priority indicator for that record will be displayed blinking.

c. Record Assign Summary - Execution of this command causes the Record Summary consisting of all assigned Trouble Tickets and Activity Messages to be displayed on the CRT, ordered by responsibility assignment. First the local TCF, by Controller, then local maintenance, then each remote TCF alphabetically.

   Any desired record may be selected by placing an "X" alongside selected record and executing SEND ALL.

Reports of two types have been provided for. As each Trouble Ticket is handled by the Coordinator, Performance Assessors or Reporter, either operator can enter an indication of reportability by placement of an "X" in the parenthesis marked DCA Reportable or O&M Reportable and operating SEND ALL. The information from that record will be sent to either the DCA Report Queue or the O&M Report Queue, as requested.

2.1.6.3 Test Operations

The primary CPMAS functions are data acquisition, analysis, and reporting. In an operational CPMAS, the initiation and control of these functions is performed by the Nucleus Subsystem. However, when the Nucleus Subsystem interfaces with either the IQCS, I/OQCS or DDMS a portion of the acquisition and analysis task is handled by the ATE mini-computer. These "Programmable" ATEs are capable of maintaining their own scan sequences, performing alarm threshold comparison, and computer trend algorithms.

The MAD, and the MAC and its options have very limited data processing capability, and thus, require detailed commands from, and interpretation of results by, the Nucleus Subsystem. The BBSA, which contains an H-316R processor, as currently programmed, has data processing capabilities intermediate between the fully programmable ATEs, and the MAD and MAC.

The types of tests performed by the Nucleus Subsystem are classified into several different categories, not all mutually exclusive.

Master tests are the sequence of operations required to extract a generic answer, without being specialized to the part of the communications system.

Master tests contain the test capability elements required to perform the test; the sequence of instructions to the ATEs; the instructions for analysis of measurements, and display formats. They do not contain the specific addresses of the data points, interpretative information peculiar to the portion of the communications system in question, instructions designating the disposition of the test results, nor scheduling. Master tests are constructed on the CRT display using the Master Test Building program.

Active tests are Master tests which contain the addresses and interpretative data required for analysis of a specific part of the communications system. They are derived from Master tests by addressing the data base with the specific communications system element upon which it is desired to make the test. If the test cannot be performed for lack of the required ATEs, the console operator will be so notified. If it can be performed, the device addresses and required interpretative data are incorporated into the Master test sequence, and it becomes a particularized test sequence. This test, for obtaining particular information upon a particular part of the network, can be stored in memory, and accessed when required. These

particularized test sequences, when stored, are termed specialized test sequences.

Demand tests are specialized tests which are initiated at operator request, or upon the occurrence of an event which has been previously designated to initiate a specialized test.

Routine tests are specialized tests which are performed periodically, on a predefined schedule. This schedule is contained in the Time Dependent Task Table. Routine tests are used to test for out-of-tolerance conditions in circumstances requiring more than a simple measurement, as, for example, when coordinated measurements are required. Routine tests also provide the data input for the statistical analysis and trending modules.

When not otherwise engaged, the Nucleus Subsystem is in its background scan mode. This is a non-interfering scan of monitor points and alarms during which parameter values and alarms are checked for out-of-tolerance conditions. If abnormalities are detected, the console operator is notified and, if so designated, appropriate demand tests initiated.

2.1.6.4 Statistics and Trends

The statistical analysis and trend module may be applied to any parameter derived from a routine, specialized test.

This module computes the following parameters of the numbers representing the series of measurements:

a. slope

b. mean (present value of trend line)

c. minimum value during period

d. maximum value during period

e. standard deviation

f. skew

g. kurtosis

h. overall mean (true mean of all measurements)

These values are available in several forms.

For the previous 24 measurements, these parameters are computed upon the parameter itself, constituting a 24 point window.

Each day, daily minima, maxima, and means are determined. The statistical parameters listed above are computed for a 31 day window for each of these three daily parameters.

At the end of each month, the statistical parameters for the month are stored, and are available for recall if desired.

2.1.6.5 Data Base

The Central Processor Data Base includes, but is not limited to: a complete description of the network topology of the circuits, trunks, groups, channels, links, and equipments that make up the system. In addition, the data base includes descriptions of the monitoring point locations that are being monitored, how they are to be tested, how it is to be presented to the console, and in what sequence the operation should be performed. These elements of the data base are site dependent and are slow changing. The data base also includes current status of all elements in the CPMAS; this portion will be time dependent, changing on a real time basis. Also in the data base are directories as necessary to retrieve the other files or portions of files.

Data Base Organization. There are nine data base special files used in the Central Processor as follows:

a. VF Circuit Record

b. DC Circuit Record

c. VF Trunk Record

d. VFCT Trunk Record

e. LINK Record

f. IMOD Record

g. BBSA Record

h. MTS Alarm Group (MAD) Record

i. MTS Measurement Group (MAC) Record

Data Base Resident Test Capability Element (TCE) Data. ATEC test capabilities exist at DC and VF levels, through baseband level. DC and VF level measurements are related to DC and VF circuit files. All other test capabilities are related to link files, unless of a miscellaneous nature. Data enabling measurements to be made are defined within the above files, as TC BITS and associated DESCRIPTIVE INFORMATION. TC or Test Capability bits are such that a set bit indicates the existence of that particular test capability.

2.1.6.6 Nucleus Subsystem Software Modules

Nucleus Subsystem software may be classified into two categories; the basic software modules which are used by the system, and the operator created programs which are used to perform particular functions.

The master test building and the display builder are basic modules. These can be used, in the field, to create test sequences and displays using other basic modules for acquisition and analysis of data.

The basic modules which existed as of June, 1975 are listed in Table 2-9. The displays which had been created as of that date are listed in Table 2-10.

2.1.6.7 Nucleus Subsystem Applicability to Digital Systems Monitoring

The Nucleus Subsystem could be expected to perform as well as a network monitor for digital systems as for analog systems.

A cursory review of the adaptations required to use the Nucleus Subsystem in the FKV system has been conducted. It shows, at least, the following minimum requirements for changes:

a. Data Base. The current data base is FDM oriented - link, trunk, and circuit. The most apparent method to accommodate a digital network is not to make minor changes in the circuit files, but create new files, with new test capability descriptors for digital groups and links.

b. ATE Control Modules. The current MAC control modules are designed around a concept of receiving data from individually addressed scanner points. With the event counter and event latch capability, and by organizing the scanners so that a given sequence of scanner points

TABLE 2-9. PROGRAM LISTING CROSS REFERENCE

PROGRAM MNEMONIC	TITLE
AA	Acquisition and Analysis Supervisor
AB	ATEC Initialization
AC	MTU Analog Command
AD	Associative Test Results Display
AF	Control and Display Alarm
AG	General Purpose Activator
AI	Associative Test File Initialization
AM	Activity Message
AN	MTU Analog Analysis
AO/AR	ASR Driver
AS	ASR Driver
AT	ASR Diagnostic
AX	Activity Message Generation
AY	Activity Message, Page 2
BA	BBSA Analysis
BC	BBSA Background Processor
BD	BBSA Display Activator
BG	BBSA Basic Scan Activator
BI	BBSA Initialization
BT(TSBLD) (TSBLD1) (TSBLD2) (TSBLD3) (TSBLD4)	Master Test Builder
BU	Build Display
BUFMG	Buffer Managerment
CB(BT) (BT2)	Caelus Bootstrap
CO	CRT Output Handler
CP	CRT Input Handler
CR	CRT Control
DA	CRT Display Access
DF	Display File Initialization
DI	Data Field Builder Initialization
DK	Storage File Initialization
DL	Display Directory List
DM	Build Data Field
DP	Test Directory Processor
DQ	DCA,O&M Report Display
DT	Acquisition and Analysis Supervisor-Data,Terminate,Preempt
D0,D1,D2,D3	Disk Driver
EP,ER	Error Print
EX	Executive Functions
FIFO FIFO2	First In First Out Queue
FPPN	Update Queue Status Lights

TABLE 2-9. PROGRAM LISTING CROSS REFERENCE (CONTINUED)

PROGRAM MNEMONIC	TITLE
GA	General File Access
GD	General File Definition
GI	General File Initialization
GTGI	Get Queue Item
HA	MTU Alarm Analysis
HC	MTU Alarm Command
HD	Disk Diagnostic
IA	I/OQCS Background Activator
IC,IN	ICCU Driver
IRUPDT	Information File Operator
IT	Acquisition and Analysis Supervisor-Initiation/Rejection
KA	Keep Alive
KB	Keyboard Utilities
KK	Disk to Disk Copy
LA	Link Test Activator
LD	Load Data Concentrator
LO	System Loader
MA	Message Analyzer
MC	Magnetic Tape Diagnostic
MD	Display, Master Test Description
MJ	Monitor Immediate Activator
MN	Manual Loopback Handler (not implemented)
MT	Magnetic Tape Driver
MVCR	Move Subroutines
NE	Create New Display
NL	Network File Load
NW	Acquisition and Analysis Supervisor-New Test Activator
OL	CRT Input Handler
PFIR	Power Failure Recovery
PJ	Phase Jitter, Frequency Offset Analysis
PR	Paper Tape Reader Driver
PT	CRT Print
QA	Queue Summary Initialization
QB	Format Queue Summaries
QC	Display Requested, Queue Summary Item
QD	Initialize Master Station Log
QE	Record Priority Summary
QF	Line Assignment Table Update
QI	Update Data Base
QJ	Queue Initialization
QMSB	Queue Management Subroutines
QP	Queue Processor
QQ	Activity Message Scheduler
QR	DCA and O&M Report Processor
QS	DCA Report Transmitter
QT	Report Transmitter
QU	Record Assignment Summary
QW	Queue Removal Processor
QX	Wait to DCA Queue

TABLE 2-9. PROGRAM LISTING CROSS REFERENCE (CONTINUED)

PROGRAM MNEMONIC	TITLE
QY	DCA O&M Queue Removal
RB	Release Buffer
RC	High Speed Paper Tape Reader Test
RP	DCA Report Summary
SA	Special File Access
SB	Seize Buffers
SM/ML/SE	Disk Driver
SQ	Acquisition and Analysis Supervisor, Test Sequencer
SS	System Status Report
SU	Special File Update
SV	Storage Allocation
SO/SZ	Sector Zero
TA	Associative Test
TD	Trender Display
TI	Random File Tidy (Clean-Up)
TL	Test Point File Load
TR	Trender
TF3D	
TT	Trouble Ticket Processor
TY	Outside Teletype
UC	Circuit File Update
UO	Off-Line Utilities
WW	Initialize Display Management
XCOM	Executive Initilization, Program Wait Mode
YA	Special File Interface
YB	Net Loss/Idle Channel Noise Analysis
YC	SAE Scan Filters
YD	SAE Scan Data
YE	Associative Test Analysis
YG	Enter Patches Into Data Base
YH	Remove Patches From Data Base
YI	La Grange Interpolater
YJ	VSWR, Forward/Reflected Power Analysis
YK	Loss and Noise Analysis
YL	Limit Check
YM	Noist Slot Analysis
YO	Noise Power Ratio Analysis
YQ	BBSA Limit Check
YS	Blocking Summaries
YY	Blocking

TABLE 2-10. CRT DISPLAY LISTING

Display Number	Title
012-000-01	DCA Reporting Display
013-000-01	O&M Reporting Display
014-000-00	Results Summary
015-000-00	Report Summary
016-000-00	Record Priority Summary
017-000-00	Record Assignment Summary
018-000-01	Trouble Ticket
019-000-01	Activity Message
019-000-99	Activity Message - Page 2
020-000-00	Master Station Log
021-000-00	DCA, O&M Report Display
024-000-00	Routine Queue Summary
025-000-00	DCA Report Queue Summary
026-000-00	O&M Report Queue Summary
027-000-00	WAIT Queue Summary
028-000-00	AM Queue Summary
079-001-01	Line Assignment Table - Page 1
079-001-02	Line Assignment Table - Page 2
079-001-03	Line Assignment Table - Page 3
079-001-04	Line Assignment Table - Page 4
190-000-01	Special File Update Master Display
190-000-02	Special File Update Authorization Display
190-000-03	Authorized Personnel ID Code List
190-000-04	Special File Item Display
190-000-05	Circuit Addition or Deletion Display
190-000-06	Circuit Patch Display
190-000-99	Special File Update Master Result Display
210-000-00	CCSD Associative Test Activation Display
220-000-00	Associative Test Results Display
270-000-00	Master Test Builder
271-000-00	Master Test Builder
272-000-00	Master Test Builder
273-000-00	Master Test Builder
274-000-00	Master Test Builder
275-000-00	Master Test Builder
276-000-00	Master Test Builder
300-000-00	IMOD Background Testing Scan Selector/Activator
301-000-00	IMOD Monitor Immediate Selector/Activator
302-000-00	Link Oriented Measurement Selector/Activator
303-000-00	BBSA Basic Measurement Selector/Activator
304-000-00	BBSA Display Test Selector/Activator
305-000-00	BBSA Translation to VF and I/OQCS Analysis Selector/Activator
310-000-00	VF-to-VF Idle Channel Noise Test Activator
311-000-00	VF Channel Out-of-Service Test Activator
312-000-00	VF Circuit Out-of-Service Test Activator
314-000-00	Reflected Power Sensor (RPS) Test Activator

TABLE 2-10. CRT DISPLAY LISTING (CONTINUED)

Display Number	Title
315-000-00	Out-of-Band Slot Noise Test Activator
316-000-00	Master Pilot Phase Jitter and Frequency Offset Test Activator
317-000-00	Link Noise/Power Ratio Test Activator
318-000-00	Baseband Switching Loopback Group Test Activator
320-000-00	In-Service VF Channel Level Measurement Test Activator
325-000-00	ILSC Transparent Seizure Test Activator
326-000-00	ILSC Conditional Seizure Test Activator
390-000-00	General Test Activator
400-000-00	Associative Test and Activity Message Blocking Display
412-300-00	ATE Blocking Summary
412-301-00	CSE Blocking Summary
412-302-00	PM Blocking Summary
500-000-00	Trend Summary Display
501-000-01	Parameter History Display - Page 1
501-000-02	Parameter History Display - Page 2
600-000-00	IMOD Background Results
610-000-00	VF-to-VF Idle Channel Noise Test Results
611-000-00	ILSC Transparent Seizure Test Results
612-000-00	BBSA Translation to VF and I/OQCS Analysis Results
613-000-00	Link Oriented Measurement Results
614-000-00	Reflected Power Sensor Test Results
615-000-00	Out-of-Band Slot Noise Test Results
616-000-00	Master Pilot Phase Jitter and Frequency Offset Test Results
617-000-00	Link Noise Power Ratio Test Results
618-000-00	Switching Loopback Group Test Results
621-000-00	Monitor Immediate Results
690-000-00	Special Results Display
694-000-00	Active Test Directory
695-000-00	Special Test Directory
696-000-00	Active Test Display
697-000-00	Special Test Display
698-000-00	General Results Display
705-000-00	Performance Assessment Function
710-000-00	Master Test Directory
712-000-00	Master Test Description
900-000-00	Display Management Tree Header Display
901-000-00	Display Management Tree Branching Display
902-000-00	Display Management Tree Format Builder Display
904-000-00	Display Management Tree Decision Table Builder Display
905-000-00	Display Management Tree Dedication Display

has a fixed meaning, system operation can be improved. To allow this, new control modules will be required for digital link functions. In addition, a control module will be required for the digital baseband monitor.

c. Data Analysis Modules. Software modules will be required to perform analysis of the baseband monitor outputs, and correlation with receiver AGC. The existing curve fitting module (Lagrangian Interpolator) is applicable for performing part of this function.

d. Test Sequences. Display constructed sequences are required for performing the background scan; the link scan; and the contingent alarm scans. These would utilize existing and newly developed ATE control modules and analysis modules, and can be constructed using the master test builder.

e. Display Creation. Eight new displays, relatively complex when compared to existing displays, are required for the FKV. These would be constructed using the display building software now incorporated in the Nucleus Subsystem software.

2.1.7 Baseband Monitor (BBM)

2.1.7.1 Description

The Baseband Monitor (BBM) group furnishes measurements of three performance related radio link parameters at the frequency division multiplex (FDM) receiver baseband. These parameters are the composite baseband rms power level, the radio pilot level, and noise level in noise slots above and below the data band. The noise level measurement works in conjunction with the Noise Stop Filter option group, implemented at the transmit end of the radio link. The BBM provides a single analog dc output which is proportional to the measured parameter level. This dc output is routed to the MAC via a form "A" scanner attachment. The BBM is depicted in Figure 2-12.

The baseband monitor can be coupled to a maximum of nine operational inputs, and to a test input jack on the front panel. The coupling device is termed the baseband coupler. This coupler is a passive device which extracts a small sample of the baseband signal for use by the BBM measurement activity.

The monitor measures the true rms level of parameters of the

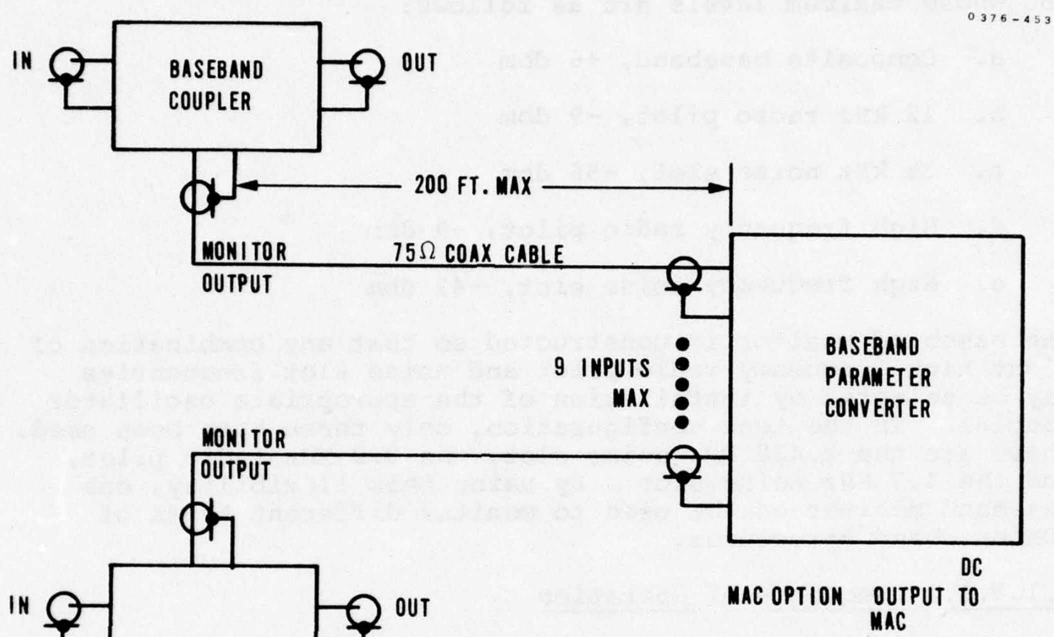

FIGURE 2-12. BASEBAND MONITOR GROUP SYSTEM CONFIGURATION

composite input signal. The output is a balanced dc voltage. Full scale output for each signal mode is +4 vdc. The full scale outputs are the resultant of single tone inputs at the BBC whose maximum levels are as follows:

a. Composite baseband, +6 dbm

b. 12 kHz radio pilot, -9 dbm

c. 36 kHz noise slot, -56 dbm

d. High frequency radio pilot, -9 dbm

e. High frequency noise slot, -42 dbm

The baseband monitor is constructed so that any combination of eight high frequency radio pilot and noise slot frequencies may be selected by installation of the appropriate oscillator modules. In the test configuration, only three have been used. These are the 2.438 MHz noise slot; the 3.2 MHz radio pilot, and the 4.7 MHz noise slot. By using this flexibility, one baseband monitor can be used to monitor different types of FDM baseband structures.

2.1.7.1.1 Sequence of Operation

Commands to the BBM are transmitted from the MAC over the option bus. A command contains three instructions; input (I), which designates the baseband to be monitored; frequency (F), which designates the frequency to be measured; and mode (M), which designates pilot or noise slot measurement. Three seconds after the command is received, the measurement is made by the MAC dc voltmeter by commanding the MAC to make a dc voltage measurement at the scanner address to which the BBM output is connected.

Capabilities and limitations for the baseband monitor are tabulated in Table 2-11.

2.1.7.2 BBM Applicability to Digital Link Monitoring

2.1.7.2.1 Applicability in Unmodified Form

The BBM can be used for three functions in its current configuration; composite level measurement, noise slot measurement, and pilot level measurement.

TABLE 2-11. BASEBAND MONITOR CAPABILITIES AND LIMITATIONS

Baseband Frequency Range	300 Hz to 10 MHz
Baseband Insertion Loss	$\leq$ 1 db with ±0.2 db flatness
Input Level	250 mV maximum
Baseband VSWR and Impedance	1.10 maximum, 75 ohms, unbalanced
Measurement Frequency Range	8 kHz to 10 MHz
<u>Standard Measurement Frequencies</u>	
Composite Baseband	8 kHz to 10 MHz
Low Frequency Radio Pilot	12 kHz
Low Frequency Noise Slot	36 kHz
High Frequency Radio Pilot	3.2 MHz
High Frequency Noise Slot	4.7 MHz
Output Levels	High Range: +4.0V to +0.4V Low Range: -4.0V to -0.4V Auto Ranging, Balanced Output
<u>Measurement Sensitivities</u>	
Radio Pilots	-6 dbm0 nom; Baseband TTL of -15 dbm, 34 db dynamic range
Noise Slots	-50 dbm0 nom, dependent on in-band noise loading level, 30 db dynamic range
Composite Baseband	Standard DCS FDM Baseband Loading Formulations relative to a TTL of -15 dbm, 34 db dynamic range
RMS to DC Conversion Linearity	±0.5 db over the dynamic range
Input Capability	10 addressable inputs; 9 Baseband Coupler inputs (remoted up to 200 cable feet maximum) 1 Baseband Parameter Converter test input

Monitoring of composite baseband level is desirable since it provides an overall measure of the baseband power level, but it does not have the same significance as it has in an FDM baseband structure, for two reasons.

First, the level of an FDM structure is determined by the sum of a multiplicity of inputs (VF channels), any one or any combination of which can go out of tolerance as a result of actions taken far from the link being monitored. In contrast, the levels within the digital baseband are determined by elements peculiar to the link itself; elements which are designed to be highly stable. Thus, the probability of an FDM baseband operating at incorrect levels is much more than that of a digital baseband.

The second reason is that baseband level does not have as direct a relationship to the quality of service provided to the user in a digital system as in an analog FDM system. In an analog system, noise is introduced into the user-to-user signal path by, among other things, intermodulation distortion which is level dependent. Because noise is cumulative in analog systems, it is desirable to detect and correct increases in the slot noise versus composite level relationship. In contrast, in the FKV digital baseband, not only is analog distortion not transmitted from link to link, but automatic gain control is used to adjust level in the T1-4000 receivers.

Slot noise can be also monitored by the existing BBM. In the FKV system, a noise slot frequency of about 8.35 MHz can be used. Measurements at Fort Huachuca have verified that the filtering at that frequency is adequate to preclude direct signal leakage from the digital baseband, the order wire, even when overloaded by +10 db, and the pilot.

Due to the design of the radio receiver, at the 8.35 MHz frequency, slot noise level is lower bounded by intermodulation distortion at RSLs of about -55 dbm (the normal, unfaded condition) and by noise below that level. At 10.5 MHz, however, the slot noise is inversely proportional to RSL ranging from an RSL of -35 dbm, downward to FM threshold. The potential advantage of using slot noise to derive a quieting curve is that departures from the receivers normal quieting curve (and, therefore, increase in threshold) can be directly determined. The disadvantage is that a property is measured which is indirectly related to performance and therefore, in itself, is a "don't care" status insofar as being controlled during design, manufacture, installation, and maintenance.

As with composite level measurement, slot noise measurements of a digital baseband are more useful than none, but do not have the relevance that they possess in a FDM system, where they directly correspond to noise introduced into the user's channel. The problem with using slot noise for digital systems performance assessment is that it can be affected by uncontrolled effects, unrelated to the quieting curve. Experience with, and testing of, digital systems may show that these effects are negligible. If so, slot noise is a viable candidate for monitoring.

The receiver pilot level is monitored by the AN/FRC-162, which uses a threshold on pilot level as a condition for switching to the alternate receiver. The pilot level on which threshold is based is also available from the AN/FRC-162, at the receiver sensor/logic/switch unit.

The radio set uses both the transmit and receive radio pilot in assessing overall equipment performance by demodulating, detecting, and comparing it to an alarm threshold. A threshold violation actuates an alarm. Both pilots are also demodulated and detected for an in-service check of the pilot deviation which is used as a presumptive indication of proper overall carrier deviation. The pilot, therefore, serves as both an equipment status monitor, by providing a check on equipment and system continuity, and a performance monitor, by providing an indication of carrier deviation.

In an FM radio link using pilots, a change in pilot level is indicative of a change in gain through the radio system. If an FDM system, pilot level is the only link level means of determining that a gain change has occurred, since the baseband level varies with loading. In a digital system, the baseband mean square level is normally constant. A change in baseband level in a digital system, therefore, conveys the same information as a change in pilot level.

While the unmodified baseband monitor is of some use for monitoring of a digital baseband, it is not as desirable as a device built especially for this purpose which could collect statistical signal deviations and measure signal amplitude.

2.1.7.2.2 Adaptability to Digital Baseband Monitoring

It is recommended that a device be developed for monitoring those properties of a digital baseband which directly relate to signal quality. The BBM is a viable candidate for this adaptation. Selectable inputs exist, as would be required in

a digital system. The frequency range is correct, except for a possible downward extension of the low frequency range. The output circuitry is suitable for providing a performance related voltage for measurement by the MAC, such as eye pattern voltage and BER.

The output from the degradation monitor is typically either an analog voltage proportional to the degree of eye pattern closure, or a "pseudo error rate" which is a gross extension of the basic error rate. In either case, the applique unit, of which the degradation monitor is a part, will perform the necessary signal measurement to achieve compatibility with the MTS option interface. The analog voltage output from the first mentioned type should be measured with a resolution on the order of 1 percent, which is possible even with very simple A/D conversion techniques. The pseudo error output from the second type must be counted to give events per unit time, and buffered.

The eye pattern monitors, in general, reflect a "smoothed" measure of system performance. The output of the device itself contains a significant amount of information. It can be easily trended to identify deteriorating system operation. In order to maximize the value of its use, however, the eye pattern data must be correlated with other monitored parameters, such as other estimates of bit error rate and radio alarms.

In an all digital network, such as the FKV system, the Bit Error Rate (BER) is to the end user the ultimate measure of communication quality. A direct measure of the overall system BER is not possible when the equipment is in-service. It is possible however to utilize idle channels in BER measurements, which accurately reflects the performance of the overall system.

The most powerful indirect technique for BER estimation is through the use of the eye pattern monitor. The output of the eye pattern monitor applique is designed to be compatible with the ATEC MTS option interface. An important feature of this form of BER measurement is that it provides a good estimate even in extremely low ($<10^{-7}$) BER environments.

The feasibility of this modification is examined in greater detail in Paragraphs 3.1 and 3.2 of this volume.

2.1.8 MAC Link Monitoring Options

2.1.8.1 Pilot Monitor (PM)

2.1.8.1.1 Description

The Pilot Monitor (PM) is an option of, and is controlled by the Monitor Telemetering Set (MTS). It is used in conjunction with the In-Service/Out-of-Service Quality Control Set (I/OQCS) to measure phase jitter and frequency offset of a frequency division multiplexer (FDM) master oscillator. The PM measures 96 kHz and 64 kHz, as synchronizing pilots. It has growth potential for two additional frequency pilots. The Pilot Monitor consists of a Pilot Translator Chassis, Pilot Interface Chassis, and Power Supply Chassis. The Pilot Translator (PT) function utilizes seven board positions in a scanner type chassis which has a thirteen circuit board capacity. The remaining positions are used to accommodate the Switching/Loopback Group control, another MTS option. The Pilot Interface chassis contains a monitor point transformer located at the pilot source. The Power Supply Chassis contains two regulated dc power supplies, ±15 Vdc, ±5 percent and +5 Vdc, ±5 percent. These supplies power the Pilot Translator and the Switching/Loopback Control.

The Pilot Translator can accommodate up to ten pilot inputs, each requiring a Pilot Interface located at the source.

The Pilot Translator selects one of the ten pilot inputs and translates it to 1 kHz for phase jitter and frequency offset measurement by the I/OQCS. The PT consists of two digital control boards, two form "C" scanner boards, an analog board, an oscillator board, and a resistor board. The Pilot Interface is a transformer which provides high bridge-on impedance to the measurement point while maintaining compatibility with the 135 ohm cable to the Pilot Translator.

Table 2-12 lists capabilities and limitations of the Pilot Monitor.

TABLE 2-12. PILOT MONITOR CAPABILITIES AND LIMITATIONS

Pilot Frequencies	96 kHz and 64 kHz (can be increased to measure up to 4 frequencies)
Frequency Translation Error	<1 Hz
RMS Deviation Translation Error	<20 percent relative to the input or 0.1 Hz whichever is greater
Input Voltage Range	5 Vrms to 5 mVrms with overvoltage protection
Input Bridge-on Impedance	>20K ohm at the Pilot Frequency
Output Level (1 kHz)	-5 dBm ±5 dB into 600 ohms, balanced load
Output Impedance (1 kHz)	<60 ohms, balanced
Input Capability	10 inputs (remoted up to 200 cable feet maximum)
Input to Input Isolation	>70 dB

2.1.8.1.2 PM Applicability to Digital System Monitoring

The Pilot Monitor is specifically designed for FDM base group application. It has no application to digital system monitoring.

2.1.8.2 Noise Stop Filter (NSF)

2.1.8.2.1 Description

The Noise Stop Filter (NSF) is a passive LC notch filter used to eliminate noise outside the baseband bandwidth prior to microwave transmission when existing noise power ratio (NPR) or "roofing" filters do not exist or are not adequate. Basically, the filters insure that received noise level above and below the baseband reflect only the noise contributions due to the elements composing the radio link, that is, transmitter spectrum splatter, transmitter noise, transmission media noise, receiver noise, and transmitter/receiver intermodulation. Typical ATEC elements which can perform an out-of-band noise level measurement are the Baseband Monitor MTS Option and the Baseband Signal Analyzer (BBSA). The Noise Stop Filter cannot be remotely

switched out-of-service, but coaxial connectors allow manual bypass. The NSF units mount in the Radio Interface Chassis (RIC) to allow operation near the link radio. Although specific center frequencies as required per installation may be used, 36 kHz and 4.7 MHz units have been developed as satisfying the majority of microwave and tropo transmission requirements.

2.1.8.2.2 NSF Applicability to Digital System Monitoring

The Noise Stop Filter is specifically applicable to FDM basebands, and is used in conjunction with the Baseband Monitor. The applicability of the concept of slot noise measurements is discussed in Paragraph 2.1.7.2.

The NSF is specifically not applicable to the FKV, as its frequencies fall into the frequency spectrum of the traffic channel. It can be adapted for digital baseband by changing the noise slot frequency.

2.1.8.3 Reflected Power Sensor (RPS)

2.1.8.3.1 Description

The Reflected Power Sensor (RPS) is used to measure the forward and reflected power within the microwave transmission feed for evaluation of VSWR. The RPS consists of two chassis: the Microwave Interface Chassis and the Power Meter Chassis. Both are mountable in standard equipment racks. They must be located within 200 cable feet distance of each other. The Microwave Interface unit must be mounted as closely as physically possible to the transmission feed monitor point.

Table 2-13 lists the Reflected Power Sensor capabilities and limitations.

TABLE 2-13. REFLECTED POWER SENSOR CAPABILITIES AND LIMITATIONS

Accuracy	<1 dB, for inputs above 5 microwatts
Sensitivity	5 microwatts
Dynamic Range	30 dB
Frequency Range	4.4 GHz to 8.2 GHz
Remote Capability	≤200 cable feet (total)

2.1.8.3.2 RPS Applicability to Digital System Monitoring

The RPS can be used in digital system monitoring, as well as, in analog systems.

Direct monitoring of the power output of the AN/FRC-162 transmitter into the waveguide structure can be performed through the existing coupler, obviating the need for forward power measurement.

The need for monitoring reflected power in modern LOS equipment is considerably less than in older designs. Isolators and circulators are used extensively to absorb reflected power. Use of these devices precludes re-reflections of the RF signal which are a source of intermodulation distortion in FDM systems and of intersymbol interference in digital systems. The AN/FRC-162 used in the FKV includes these devices. If waveguide re-reflections become a problem of severity sufficient to impair communications, it will cause intersymbol interference, which is detectable in the received eye pattern. If its nature is to appreciably lessen radiated power, received signal level will drop.

In summary, the RPS can be applied to the FKV, but is not considered cost-effective.

2.1.8.4 Switching/Loopback Group (SLG)

2.1.8.4.1 Description

The Switching/Loopback Group (SLG) option furnishes loopback of baseband and IF signals to their source. Auxiliary switching is also provided for limited DC and VF signals.

The SLG is composed of three rack mounted chassis: the Radio Interface Chassis (RIC), the Switching Loopback/Pilot Translator Chassis (SL/PT), and the Power Supply Chassis. The RIC houses any three of the following:

a. Baseband Relay

b. IF Relay

c. Blank Panel

d. Interconnection Panel

e. RIC Mountable Subassemblies associated with other options

The SL/PT chassis contains the control cards to actuate the baseband or IF relays. The control cards share the chassis with the control cards for the Pilot Monitor. Card location A10 through A13 can be utilized for auxiliary switching of DC and/ or VF signals. The controls and logic are similar to the ones required for loopback operation. The Baseband Relay (BBR) provides one-way loopback of a full duplex link. The relay is located, electrically, between the multiplex and radio equipment.

The Intermediate Frequency Relay (IFR), performs two-way loopback using a coaxial transfer switch to loop both links on either side of the relay break point. RFI filtering prevents control line pickup of unwanted signals by the IF relay.

Table 2-14 lists capabilities and limitations of the SLG.

2.1.8.4.2 SLG Applicability to Digital System Monitoring

The usefulness of the Switching and Loopback Group in digital systems is more limited than with FDM systems.

In analog systems, where degradation is cumulative, loopback can be performed at increasingly distant sites to isolate sources of degradation. In digital systems, loopback past the next point of signal regeneration will provide no information unless the degradation is so severe that an appreciable error rate is introduced.

Loopback can be performed at baseband in sites adjacent to the side with measuring facilities, and the analog degradation observed and compared in the normal and looped mode.

The potential advantage of loopback methods of degradation isolation is low expense insofar as the more complex measuring equipment can be placed at a central site. The obvious disadvantage is that service is disrupted during testing.

2.1.8.5 Noise Loading Group (NLG)

2.1.8.5.1 Description

The Noise Loading Group (NLG) consists of five types of equipment interconnected to provide selective group and supergroup noise loading capability for a frequency division multiplexer (FDM) set. The NLG also provides selective in-band noise power ratio (NPR) measurements of unloaded groups and supergroups or of specific channels. The programmable amplitude and controlled spectral characteristics of the noise test signal allow testing of intermodulation distortion generated by FDM systems. The

TABLE 2-14. SWITCHING AND LOOPBACK GROUP CAPABILITIES AND LIMITATIONS

Frequency Range	
Baseband Relay	300 Hz to 10 MHz
IF Relay	60 MHz to 80 MHz
VSWR	
Baseband Relay	<1.1 over baseband frequency range
IF Relay	<1.15 over IF frequency range
Impedance	75 ohms, unbalanced
Insertion Loss	0.2 dB for the "normal through" path and the loopback path
Crosstalk and Isolation	
Baseband Relay	>95 dB crosstalk between the transmit and receive "normal through" paths
	>60 dB isolation for the normal transmit and receive signal paths during loopback operations
IF Relay	>65 dB crosstalk between the transmit and receive "normal through" paths
	>50 dB isolation for the normal transmit and receive signal paths during loopback operations
Switch Contacts	Hermetically sealed
Relay Voltage	±15 Vdc
Baseband Attenuator	
Frequency Range	300 Hz to 10 MHz
Impedance	75 ohms, unbalanced
Attenuator	16 dB to 46 dB in 2 dB steps
Attenuator Accuracy	±0.25 dB plus 1 percent of attenuator setting
Power Dissipation	0.25 watt average

elements which comprise the Noise Loading Group are:

a. Group/Supergroup Noise Generator (G/SGNG)

b. Supergroup Switch (SGS)

c. Supergroup Switch Patch Panel (SGSP/P)

d. Group Switch (GS)

e. Group Switch Patch Panel (GSP/P)

Interface to the FDM is at the supergroup and group distribution frames by way of the SGSP/P and GSP/P. Provision is made within the SFSP/P and GSP/P, for manual lockout of selected supergroups or groups in order to prevent undesired circuit breaking or noise loading within the locked out channel. In the event of a power failure, all channels go to the normal through configuration.

The Group/Supergroup noise source is furnished by a common pseudo-random digital noise generator. Level stabilizers are used to maintain the noise source output at 10 volts peak-to-peak. A 200 millisecond repetition rate and a 20 bit random word pattern through a ring counter provide $2^{20}-1$ different digital states to insure nearly pure white distributed noise and spectral content in 5 Hz increments. A bit interval of 200 nanoseconds, as provided by a stable clock oscillator, insures a uniform magnitude response for the Group and Supergroup frequency ranges. The generator output is divided into Group and Supergroup frequencies, by passive bandpass filters. Provision for clearing of injected noise within the specified VF channels at the low and high ends of the Group and Supergroup frequency bands is accomplished by notches at the band edges of each filter. Use of programmable attenuators of a reed relay design provide maximum isolation and repeatability. A single threshold level monitoring circuit senses the output from the attenuators to detect gross failures in output level or significant deviation from preset levels.

Table 2-15 tabulates capabilities and limitations of the NLG.

2.1.8.5.2 NLG Applicability to Digital System Monitoring

The equipment in the noise loading group is specifically tailored for testing FDM systems and, as such, is not applicable to digital systems.

TABLE 2-15. NOISE LOADING GROUP CAPABILITIES AND LIMITATIONS

Characteristics	Description
Interfaces	
Supergroup Signal Interface	
Connections	Christmas tree terminal block
Characteristic Impedance	75 ohms, unbalanced
Frequency Range	312 kHz - 552 kHz (min)
Input VSWR (max)	1.05 except during noise loading, 1.2 during noise loading
Output VSWR (max)	1.05
Isolation	75 dB (min)
Noise Loading Level per Supergroup	+4 dBm (Supergroup Noise Generator at maximum output)
Group Signal Interface	
Connections	Christmas tree terminal block
Characteristic Impedance	135 ohms, balanced
Frequency Range	60 kHz - 108 kHz (min)
Input VSWR (max)	1.05 except during noise loading, 1.2 during noise loading
Output VSWR (max)	1.05
Isolation	75 dB (min)
Noise Loading Level per Group	-20 dBm (Group Noise Generator at maximum output)
Outputs	
Noise Generator	
Group Switches	8 outputs (max) at up to 200 cable feet
Supergroup Switches	8 outputs (max) at up to 200 cable feet
Connectors (All)	Twinax

TABLE 2-15. NOISE LOADING GROUP CAPABILITIES AND LIMITATIONS (CONTINUED)

Characteristics	Description
Outputs (Continued)	
Noise Generator (Continued)	
Noise Loading Group Spectral Density	±3 dB of nominal from 68 kHz to 100 kHz; greater than 60 dB below nominal for frequencies between 56 kHz to 64 kHz and 104 to 112 kHz; greater than 40 dB below nominal for frequencies below 56 kHz and about 112 kHz
Noise Loading Supergroup Spectral Density	+3 dB of nominal from 340 kHz to 524 kHz; greater than 60 dB below nominal for frequencies between 280 kHz to 320 kHz and 544 kHz to 584 kHz; greater than 40 dB below 280 kHz and above 584 kHz
Levels	Controllable in 1 dB steps over 30 dB range to -20 dBm (max)
Switching Capacity per Chassis	
Supergroup	Up to 10 supergroups
Group	Up to 25 groups
Patch Panel Impedances	
Supergroup	75 ohms, unbalanced
Group	135 ohms, balanced

2.1.8.6 Idle Line Seizure Controller (ILSC)

2.1.8.6.1 Description

The ILSC determines the VF channel idle/busy status and seizes idle channels for channel testing. ILSC utilization is on interswitch AUTOVON trunks and subscriber lines with 2600 Hz SF (single frequency) signaling. The ILSC has three major operating modes:

a. Bridge-on detection mode - determines the Tx and associated Rx line idle/busy status.

b. Transparency seizure mode - performs a single point seizure with replacement of the 2600 Hz SF signal during idle periods. The seizure and SF replacements occur on both transmit and receive lines. The ILSC monitors both lines before the seizure point to determine when a call for service occurs. A call for service causes the ILSC at the seizure end to restore the line for normal usage independent of the measurement status. Since there is no communication necessary between the seizure point and measurement end, the restoring time is less than 50 milliseconds, the time of detecting a call for service and reed relay switching.

c. Conditional seizure mode - identical to the transparent seizure except service is not restored until testing is complete. The conditional seizure mode is utilized to provide a two point seizure for out-of-service testing.

In addition to the three operating modes the ILSC has three system utilization modes.

a. Normal test mode - seizure is performed during idle periods and is transparent to the user. The transparency is obtained by restoring the lines upon request for service. The normal usage mode is utilized for measurements of:

- Idle channel noise
- Channel gain
- 2600 Hz phase jitter
- Phase hits

- Amplitude hits
- Dropouts
- Noise frequency

The measurement is between the seizure point and any down-stream bridge-on measurement point.

b. Special test mode - two point "conditional seizure" for out-of-service testing. Seizure is performed during idle periods and does not restore service until testing is complete. The 2600 Hz signals are replaced during seizure on lines external to the two point seizure link. The special test mode is utilized for out-of-service measurements of:

- Envelope delay
- Intermodulation distortion
- Harmonic distortion
- Frequency response
- Impulse noise
- Loopback tests
- Special tests

c. Maintenance mode - provides bridge-on line status (if necessary) before seizing by normal MTS or I/OQCS operation.

2.1.8.6.2 ILSC Applicability to Digital System Monitoring

The ILSC is intended for use on VF channels employing 2600 Hz in-band signaling and, as such, has the same applicability in a PCM/TDM system as it currently has in a FDM system. It will seize a channel upon recognition of an on-hook 2600 Hz tone for out-of-service testing by an I/OQCS. The ILSC is not recommended for FKV demonstration testing since its operation would not differ from that in a FDM system.

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- Amplitude hits
- Dropouts
- Noise frequency

The measurement is between the seizure point and any down-stream bridge-on measurement point.

b. Special test mode - two point "conditional seizure" for out-of-service testing. Seizure is performed during idle periods and does not restore service until testing is complete. The 2600 Hz signals are replaced during seizure on lines external to the two point seizure link. The special test mode is utilized for out-of-service measurements of:

- Envelope delay
- Intermodulation distortion
- Harmonic distortion
- Frequency response
- Impulse noise
- Loopback tests
- Special tests

c. Maintenance mode - provides bridge-on line status (if necessary) before seizing by normal MTS or I/OQCS operation.

2.1. 8 .6.2 ILSC Applicability to Digital System Monitoring

The ILSC is intended for use on VF channels employing 2600 Hz in-band signaling and, as such, has the same applicability in a PCM/TDM system as it currently has in a FDM system. It will seize a channel upon recognition of an on-hook 2600 Hz tone for out-of-service testing by an I/OQCS. The ILSC is not recommended for FKV demonstration testing since its operation would not differ from that in a FDM system.

2.1. 8 .7 Voice/Data Combiner (V/DC)

2.1. 8 .7.1 Description

The Voice/Data Combiner (V/DC) option is used to provide simultaneous and independent, voice and narrowband VF FSK communications over voice grade communication channels, such as order wire circuits. The V/DC consists of a Speech Plus Data Panel and a Data Modem Interface (DMI). The Speech Plus Data Panel is a standard Lenkurt Unit with an in-band FSK data channel centered at 1920 Hz. The unit handles the ATEC 150 baud data rate and 2600 Hz in-band signaling tones. The DMI contains power supply, FSK modem boards and universal, strappable, gain VF amplifiers. The amplifier is utilized for level normalization, as required, for each installation. The DMI is expandable to handle two full duplex data terminals.

2.1. 8 .7.2 V/DC Applicability to Digital System Monitoring

The Voice/Data Combiner is applicable to any system, analog or digital, having only a VF bandwidth order wire. It is not required in the FKV network because a VF bandwidth channel from 4-8 kHz, separate from the voice order wire, is available for telemetry.

2.2 POTENTIAL MONITOR QUANTITIES VERSUS ATEC CAPABILITIES

The Statement of Work for this study, in Paragraphs 4.1.5, 4.1.6, and 4.1.7 lists quantities which are potentially monitorable in a digital system, and directs analysis of the present ATEC system for monitoring these quantities.

The basic scope of this study is to determine: (a) what parameters should be monitored in the FKV transmission system, and (b) how it can be done using components of the AN/GYM-12 system. Therefore, other sections of this report contain detailed rationale for, and examples of, monitoring of digital system parameters by ATEC equipments, along with descriptions of recommended adaptations. Because of this thorough coverage of most of these topics in the rest of the report, a thorough analysis of all potential monitored quantities in this section would only increase verbosity without contributing to clarity.

The basic approach of this section is, therefore, to direct the reader to other sections where the topic is treated in detail, and in context.

2.2.1 Alarm Monitoring

Alarms can be monitored in two forms: (a) As "hard" alarms, whose reported status is that of the alarm when scanned, and (b) As "latched events", in which the quantity sensed is whether or not the alarm has activated once or more during a delineated period of time. Both types are recommended for the FKV system because hard alarms need to be detected when scanned, while latched events may be stored for later processing such as correlation with detected error bursts.

Hard alarms are monitored by the alarm scanner. Its characteristics are described in Volume II, Paragraph 2.1.1.1.1. Hard alarms to be monitored are shown in Volume I, Paragraph 3.7. Latched events, to be monitored by the ATEC system, require adaptations. Modifications to the analog scanner are recommended to provide this capability, and are discussed in Paragraph 3.2.1.

2.2 Eye Pattern Monitoring

Eye patterns, and possibly significant parameters derived therefrom, cannot be monitored by ATEC components without adaptation.

Eye pattern monitoring is recommended for the FKV because it provides both a present time performance measure and a predictive margin measure extremely useful in performance assessment.

Requirements for eye pattern monitoring are introduced in Section 2.2.5 of Volume I and are discussed in considerable depth in Appendix A to this volume.

The recommended method of monitoring the eye pattern is through development of new circuit cards for the baseband monitor. This adaptation is described in Volume II, Paragraph 3.2.2.

2.2.3 Bit Error Rate (BER)

Bit error rate can be measured by an unadapted ATEC system, in a restricted fashion. This is through measurement of impulse noise counts on an idle PCM derived VF channel. This method of interring error rate is discussed in Appendix B to Volume II.

This method of inferring BER is deemed inadequate for digital transmission system monitoring for the following reasons:

(a) An idle channel and an I/OΩCS impulse noise counter are required for each entity monitored.

(b) Error properties of the individual high speed digital links cannot be inferred except where the 1.544M bps digroup traverses only one high speed digital link.

The method of measuring bit error (a parameter recommended in Volume I, Paragraph 3.6.2 and Appendixes 2, 3, and 4) is counting of framing bit errors on the T1-4000, T1WB1, and D-2 receiving demultiplexers. This requires adaptations to the ATEC analog scanners, which are discussed in Volume II, Paragraph 3.2.1.

2.2.4 Jitter

Jitter in VF channels can be measured by the I/OQCS on an out-of-service basis. However, as discussed in Appendix B, Paragraph B-8, PCM systems do not introduce jitter of sufficient severity to warrant operational monitoring.

Jitter of low speed digital streams (up to 10K bps) can be measured by the DDMS. Modifications to the DDMS can increase this to 50K bps. The desirability and feasibility of this modification are discussed in Volume II, Paragraph 3.1.4.

Unmodified ATEC equipment cannot monitor jitter at the 1.544M bps T1 rate or the 12.6M bps baseband rate. Operational monitoring of jitter is discussed in Volume I, Paragraph 2.2.4.3, in which it is concluded that, in the FKV, monitoring of jitter at the T1 rate is unproductive because the large value of inherent T1 jitter which occurs as a consequence of the T1-4000 stuff-destuff multiplexing.

2.2.5 Radio Pilot

Radio pilot level monitoring as an alarm at the receiver is recommended as a component of the radio Rx alarm that is used in the Sudden Service Failure Sensing System. See Volume I, Subsection 3.9.

With a statistically stationary baseband signal, monitoring of baseband level provides, in a manner more directly related to mission channel performance, the same information as monitoring pilot level; namely; system gain. Therefore, its use is recommended in lieu of analog pilot level measurements.

2.2.6 Receiver AGC

Receiver AGC is monitorable by the MAC through the analog scanners, with no adaptations. Its use is recommended as a means of determining apparent received signal level (RSL).

The AN/FRC-162 squelch alarm is, in essence, activated at a threshold on AGC voltage. It is monitorable directly by the alarm scanner, without adaptation, or its occurrence can be latched on an analog scanner with event latch modifications.

The requirements for monitoring RSL are discussed in Volume I, Paragraph 2.2.5 and Volume I, Appendix A-5. Its use in system outputs is discussed in Volume II, Subsection 3.4.

2.2.7 Diversity Combiner Activity

The diversity combiner in the FKV system is the baseband sensor/ logic/switch receiver.

Diversity action might be monitored for two reasons; to provide network control with knowledge of fading activity in real time, and to measure the relative performance of the two receivers by measuring the relative amount of time each is in service.

The ATEC system can monitor this acitivty by inclusion of the indicator of which receiver is in use in the alarm scan. However, we have chosen to recommend a different method; monitoring of the individual receiver squelch alarms. These provide an indication of fading activity through indicating that an individual receiver has sensed a signal level below the alarm threshold.

Determination of the relative times of operation of the two receivers is not recommended for two reasons.

First, the criteria for switching to the alternate receiver are loose. As specified in Amendment 3 to DCSS-1-70(A), the specification to which the radio has been procured, switching will occur when the RSL of the in-service set is -66 ±3 dBm, and the RSL of the out of service unit is 5 ±2 dB better. This effectively allows ±2 dB

difference in the switching criteria, which corresponds to a ratio of 2.5 to 1 in the expected time below threshold. This is presumably acceptable operationally because it affects user service in a second order fashion, but clouds judgement upon relative performance of the two diversity legs.

Second, on all links, fading will be rare at some times of the year, and, on some links, fading will be rare at any time of the year. Under nonfading conditions, switching will not occur (except for equipment failure), and the receiver with the most in-service time will be the one which the maintenance technician left in service after his last service call. Under these conditions, a measure of relative time each receiver is in use will reflect technicians proclivities, not relative equipment performance.

For completeness, it should be noted that the foregoing rationale does not apply to FDM tropospheric scatter systems. In these systems the parameter upon which combining is based is out-of-band slot noise, which is directly related to the service provided to the user. Fading of any signal leg of a system is the normal node of operation, which makes negligible any bias due to the state of the equipment immediately after maintenance.

2.2.8 Link Noise

Link noise, in the form of slot noise, is measurable by the existing baseband monitor, with proper selection of crystal oscillator frequencies. This application of the BBM is discussed in Volume II, Paragraph 2.1.7.

The recommended means of monitoring link noise is through eye pattern measurements of baseband signal dispersion.

Eye pattern monitoring is discussed in Paragraph 2.2.2.

2.2.9 Received Signal Level (RSL)

RSL is monitorable by the ATEC system through measurement of receiver AGC. This usage is discussed in Paragraph 2.2.6.

2.2.10 VF Channel Parameters

The I/OQCS is capable of measuring a large range of VF channel parameters without adaptations. Adaptations could increase its usefulness considerably.

Use of the I/OQCS is discussed in Volume II, Paragraph 2.1.3. A possible TSS adaptation for use with the I/OQCS is outlined in Volume II, Paragraph 3.1.6.

The MAC will also measure some VF channel parameters. Its capabilities are discussed in Volume II, Paragraph 2.1.1.2.

2.3 SUMMARY OF ATEC APPLICABILITY

2.3.1 General

The preceding sections have discussed the methods in which ATEC equipment may be applied to digital transmission system monitoring; the applicability of ATEC equipments to monitor specific digital systems parameters, and ATEC hardware and software adaptations for digital systems monitoring. This analysis has been performed in three contexts, viz:

a. Applicability, in the abstract, to monitoring systems using digital transmission systems.

b. Desirability of utilization in the specific application of operational monitoring of the FKV system.

c. Desirability of incorporation in the test bed system for evaluation in 1977.

A summary of equipment applicabilities is shown in Table 2-16.

2.3.2 Non-Recommended Equipment Utilization

Some ATEC elements have been found to be applicable in general to digital systems monitoring, but not recommended for FKV implementation. The reasons for not recommending FKV usage are discussed below, by individual elements.

a. Nucleus Subsystem (NSS)

In the abstract, the Nucleus Subsystem would appear to be a logical choice for the central site data processing unit, since it contains many of the qualities which are required for the central processor. However, the development and debugging of the required digital systems software would require use of the nucleus for several months. This, in turn, would entail either serious interference with the planned Operational Test and Evaluation, or the purchase of another copy of the System. The first alternative is precluded, while the second is expensive.

A related consideration is the ultimate approach to be adopted toward transmission systems monitoring. Development of the PATE as the data processing element for small networks meshes with evolving ATEC element utilization concepts, while utilization of the NSS would be a dead end street. It is, therefore, logical to channel development effort toward the ultimately envisioned system, rather than toward a single shot effort.

TABLE 2-16. SUMMARIZED ATEC APPLICABILITY FOR DIGITAL SYSTEM MONITORING

ATEC EQUIPMENT	APPLICABLE WITHOUT MODIFICATION	APPLICABLE WITH ADAPTATIONS	NOT APPLICABLE
NSS CONSOLE	OPERATOR INTERACTION		
NSS CENTRAL PROCESSOR & DATA CONCENTRATOR	TELEMETRY		
NSS SOFTWARE		DATA PROCESSING	
* PATE SOFTWARE		DATA PROCESSING	
PATE *IQCS,I/OQCS,DDMS	VF QUALITY, LOW SPEED DATA	50Kbps DATA (T1WB1)	
* PATE CRT & PRINTER	OPERATOR INTERACTION		
* PATE LINE INTERFACE	TELEMETRY		
* ANALOG SCANNER	VF QUALITY DC VOLTS	EVENT COUNTER EVENT LATCH	
TSS	VF QUALITY		
MSMS	VFCT QUALITY		
* MAD	ALARM		
* AS	ALARM		
* AD	ALARM		
* MAC	VF QUALITY DC VOLTS EVENT COUNTER EVENT LATCH		
* BBM	BASEBAND ACTIVITY	BASEBAND EYE MONITOR	
SLG	BASEBAND LOOPBACK		
NSF		BASEBAND QUALITY	
RPS	WAVEGUIDE REFLECTIONS		
NLG			N/A
PM			N/A
V/DC	TELEMETRY		
ILSC	VF QUALITY		
BBSA			N/A

* Recommended for the ATEC/FKV Demonstration

b. Switching/Loopback Group (SLG)

The SLG can be utilized in digital transmission systems, but not as effectively as in analog systems. These considerations are discussed in more detail in Volume II, Paragraph 2.1.8.4.

Use of the loopback unit at alternate sites, in lieu of a baseband monitor, could provide some reduction in system cost. However, individual link performance margin assessment could only be done on an interruption of service basis, and could not produce results as positive as those achieved through individual link monitoring. Loopback methods were, therefore, rejected in favor of continual individual link performance assessment.

c. Reflected Power Sensor (RPS)

Progress in microwave equipment technology has made multiple waveguide reflections a much less probable phenomenon in modern equipment than in the past. Insofar as deleterious reflections are judged to be less likely, but, if they do occur, are detectable at baseband, the direct monitoring of reflected power is considered unrewarding.

d. Voice/Data Combiner (V/DC)

The Voice/Data Combiner system is for the purpose of allowing ATEC telemetry to be superimposed upon an analog voice order wire.

Since the FKV network has a 4 to 8 kHz analog channel available for telemetry, this capability is not required.

e. Idle Line Seizure Controller (ILSC)

The ILSC recognizes idle VF channels and seizes them to enable non-interfering out-of-service measurements to be made.

The ILSC is most effective at VF nodal points, where large numbers of VF circuits are concentrated, and where the orientation is upon circuits.

For specific FKV monitoring, it has been judged adequate to measure the transmission characteristics of VF channels infrequently, on a quality control basis, not requiring the ILSC. If this judgment is incorrect, this capability can be added without impacting upon the basic question of digital transmission system monitoring.

f. Noise Stop Filter (NSF)

The NSF is employed to eliminate noise outside of the baseband bandwidth prior to microwave transmission when "roofing" filters do not exist or are inadequate.

The NSF is not applicable to FKV because its frequencies fall into the frequency spectrum of the traffic channels. It can be adapted for digital baseband by changing the noise slot frequency.

g. Digital Distortion Monitoring Set (DDMS)

The DDMS is a computer controlled automatic test system designed to perform in-service monitoring, alarm sensing, and trend analysis of digital data signals. The DDMS will measure and evaluate asynchronous data from 25 to 10,000 bits/second and synchronous data from 50 to 10,000 bits/second.

The DDMS is applicable to digital system monitoring through its ability to measure the performance of in-service low speed data lines (0-9600 bps) before and after transmission through the digital system, thereby enabling the detection of equipment malfunction resulting in signal degradation.

With modifications (hardware and software), the DDMS can accommodate higher (up to 50,000 bps) digital rates.

2.3.3 Inapplicable for FKV Demonstration

Modification of one ATEC element, the Test Signal Source (TSS) has been judged to be ultimately desirable, but has not been recommended as an objective of the test program.

The TSS is an integral component of the I/OQCS, and an optional component of the MAC. It generates test signals for out-of-service testing of a VF channel.

As currently configured, the TSS uses frequencies which are submultiples of, or bear simple harmonic relationships to, the 8 kHz PCM sampling frequency. Results of testing over a PCM channel are, therefore, sometimes erroneous. Modifications are required to ameliorate this effect.

Increasing utilization of PCM transmission militates for ultimately developing and deploying these modifications. However, these modifications are not needed for the specific objective of determining ATEC applicability to digital transmission systems monitoring.

2.3.4 Non-Applicable ATEC Equipment

The following ATEC elements are specifically configured for monitoring frequency division analog systems, and have no applicability to digital systems.

Baseband Signal Analyzer (BBSA)

Noise Loading Group (NLG)

Pilot Monitor (PM)

2.3.5 Applicable ATEC Equipment for Demonstration

The ATEC equipment recommended for the FKV system monitoring and test program (the starred items in Table 2-16) are listed below.

- PATE-IQCS: Applicable without modification to measure in-service VF channel parameters.
- PATE CRT & PRINTER: Applicable without modification to provide operator interaction.
- PATE LINE INTERFACE: Applicable without modification for telemetry.
- PATE SOFTWARE: Applicable with modification for data processing.
- MAD, AD, AD: Applicable without modification to process alarms.
- ANALOG SCANNER: Applicable without modification to route analog signals to a measurement device. Applicable with modification to provide event latching and counting.
- MAC: Applicable without modification for dc voltage and VF measurements and to provide event latching and counting.
- BBM: Applicable with modification to monitor baseband eye pattern quality.

2.4 ATEC SCAN TIME CONSIDERATIONS

2.4.1 Nodal Control System Configuration

An FKV implementation employing the applicable ATEC equipments identified in the preceding paragraphs would consist of:

a.	Site Equipments:	Alarm Scanners, MAC Groups, Analog Scanner, and BBM
b.	Nodal Control Center:	Display Group, MAD, Central Processor (PATE-IQCS), and Output Devices

As defined in Volume I, Paragraph 2.2.6, the reaction time demands on the ATEC system configuration would be:

Loss of Service	30 seconds maximum
Loss of Standby	5 minutes maximum
Equipment Degradation	30 minutes maximum
ATEC Equipment Degradation	1 hour maximum
Telemetry Degradation	1 minute maximum

2.4.2 Scan Time

The time required to scan a system parameter or make an observation is a function of the parameter type and the telemetry data rate. In the FKV, it is convenient to distinguish between the following parameter types; major alarms, alarms, analog parameters, digital parameters, analog parameters related to maintenance, and status indicating parameters.

2.4.2.1 Alarm Scanning

Alarms are equipment related alarms which do not indicate loss of service. In an ATEC environment, they are sensed as voltages or contact closures by an Alarm Scanner. As discussed in Paragraph 2.1.1.1.1, the Alarm Scanner is implemented in increments of 10 alarms from 10 to 50 alarms total. Hence, the time to scan alarms is incremented each time the total number of alarms is larger than a multiple of 10. As shown in Table 2-1, the PATE to MAD data organization requires an average of 10 seconds to scan 50 alarms, an average of 8.2 seconds to

scan 40 alarms, and an average of 6.5 seconds to scan 30 alarms.

<u>2.4.2.2 Major Alarm Scanning</u>

As each set of 5 alarms (which are formatted in a single ASCII character) are scanned by the MAD, the status of a major alarm bit in the ASCII character is checked. The time between reception of each 10 bit character containing a major alarm indicator bit is (10 + 15)/75 = 0.3 seconds since each 10 bit character is separated by 15 bits of mark space and the data rate is 75 baud.

Figure 2-5A illustrates that the total time required by a PATE to query and receive a major alarm acknowledgment from a MAD is 0.3 seconds. This is determined by the time required to transfer five 10 bit characters at 150 baud.

<u>2.4.2.3 Analog Parameter Scanning</u>

As discussed in Paragraph 2.1.1.2, analog parameter (dc voltage) measurements by the MAC require 3.7 seconds if the measurements are made singly or 2.5 seconds if the MAC is operated in a scanning mode. Since the scanning mode of measurement is employed in the FKV monitoring system, the monitor requires 2.5 seconds per analog parameter measured.

<u>2.4.2.4 Digital Parameter Scanning</u>

The MAC may be employed to measure parameters classified as digital if, for the purposes of measurement, the digital parameters are converted into analog voltages. Hence, for FKV implementation, digital parameter measurements may be assumed to require 2.5 seconds per scanned parameter.

<u>2.4.2.5 Maintenance Analog Parameter Scanning</u>

Analog parameters related to maintenance require 2.5 seconds per parameter measurement as is the requirement of normal analog parameters.

<u>2.4.2.6 Status Parameter Scanning</u>

Status indicating parameters are in the form of contact closures and may be scanned by means of an Alarm Scanner and associated MAD. If scanned by an Alarm Scanner, the scan rates associated with alarm scanning applies.

At SGT, the combined number of alarms and status parameters exceeds 50 which is the capacity of a full Alarm Scanner. To

scan the remaining status parameters, there are two alternatives. First, another Alarm Scanner could be installed at SGT. Secondly, the remaining status parameters could be monitored by an Alarm Scanner if they are regarded as two-valued analog signals. Since status parameters do not have to be scanned as often as alarms (if the converse were true, they would be classed as alarms), it is cost effective to employ the latter implementation and scan the remaining status parameters by means of the analog scanner at SGT. This scanner has excess attachment points. The analog scan rate of 2.5 seconds per monitor point would apply to these remaining status parameters.

2.4.2.7 Net Scan Time

Using the ATEC equipment scan times discussed above, the total scan time for a site is best explained by means of a hypothetical example. Assume that a site has the following parameters:

10 major alarms	MA
50 alarms	A
20 analog parameters	AP
20 digital parameters	DP
10 analog parameter/maintenance	AP/M
20 status parameters	S

Based upon the preceding discussion, the total CPU command to CPU data receipt time to scan all parameters of each type at the site would be:

MA	10 requires	0.33	seconds
A	50 requires	10.0	seconds
AP	20 times 2.5 requires	50.0	seconds
DP	20 times 2.5 requires	50.0	seconds
AP/M	10 times 2.5 requires	25.0	seconds
S	20 requires	4.8	seconds (classed as alarms)

The preceding times are absolute, that is, they do not indicate what percentage of a given time interval specific parameters are being observed. Determining normalized time requires that the frequency with which particular parameter types are scanned also be stated.

Assume the following scan frequencies for this hypothetical system:

MA	30 seconds
A	5 minutes
AP	15 minutes
DP	10 minutes
AP/M	6 hours
S	10 minutes

Noting that the fastest rate corresponds to scanning major alarms every 30 seconds, the other rates may be normalized to the 30 second rate. Scanning 50 alarms requires 10 seconds of each 5 minutes as indicated above. 10 seconds per 5 minutes is equivalent to 2 seconds per minute or 1 second per 30 seconds. Similarly, scanning 20 analog parameters every 15 minutes requires 50 seconds per 15 minutes or 1.67 seconds per 30 seconds.

In like manner, the normalized scan times for the site may be shown to be:

MA	0.33 seconds per 30 seconds
A	1.0 seconds per 30 seconds
AP	1.67 seconds per 30 seconds
DP	2.5 seconds per 30 seconds
AP/M	0.03 seconds per 30 seconds
S	0.24 seconds per 30 seconds
Total	5.77 seconds per 30 seconds

The total time required to scan all alarms, normalized to 30 seconds, is 5.77 seconds out of 30 seconds. Hence, in a given 30 second period, the monitoring system would only have to devote 5.77 seconds to parameter collection at this example site.

2.4.3 Scan Sequence for Hypothetical System

Scan sequencing employed within a total performance measuring system is also best explained by way of an example. Suppose the total number of parameters in the entire three site system is as follows:

Parameter Type	Total	Time Required Total
MA	3 sites	0.99s
A	4 scanners (50 alarms each)	40 s
AP	200	500 s
DP	100	250 s
AP/M	50	125 s
S	3 scanners (10 alarms each)	9 s

Again, the smallest scan denominator is 30 seconds. If the major alarms are to be scanned every 30 seconds, then 0.99 seconds out of every 30 seconds should be devoted to a major alarm scan. Next, scanning all alarms requires 40 seconds every 5 minutes or 4 seconds every 30 seconds.

Noting that the alarm scans require 10 seconds for each of 4 scanners, the alarm scan may be accomplished by scanning one alarm scanner for 10 seconds for 4 consecutive 30-second intervals and neglecting the alarm scan for 6 30-second intervals (5 minutes total) whereupon the sequence is repeated. Analog parameters require 500 seconds every 15 minutes or 16.7 seconds every 30 seconds. Hence, an average of 16.7 seconds should be devoted to analog parameter scanning every 30 seconds. In a similar manner, 8.3 seconds every 30 seconds could be devoted to digital parameter scan and 0.2 seconds to analog maintenance parameters. One status alarm scanner could be checked in approximately 1 of every 7 30-second interval.

Thus, it is evident that there may be no definite scan sequence that is exactly repeated over and over. The processor simply devotes average times to the various parameter types such that all parameters of a given type are scanned in the required length of time.

Based upon scan sequence data per the illustrative example, Table 2-17 presents a plausible scan sequence as might be employed within the FKV, and not the hypothetical system assumed for explanatory purposes. The table shows that all major alarms are checked every 30 seconds, all alarms (note 8.2 seconds devoted to HDG) are scanned every 3 minutes or six 30-second intervals, etc.

TABLE 2-17. FKV SCAN SEQUENCE EXAMPLE

TIME					
Major Alarms	2.31 S		Major Alarms		
Alarms - HDG	8.2 S	1	•		5
AP-HDG	17.5 S		•		
	28.01 S		•		
Major Alarms	2.31 S				
Alarms - SWN	6.5		•		
AP - HDG	15.0 S	2	•		6
AP - SWN	7.5 S		•		
	31.31 S		3 minutes (time to begin repeat of alarm scan)		
Major Alarms	2.31 S				
Alarms - KSL	10.0 S	3	Major alarms	2.31 S	7
AP - SWN	17.5 S		Alarms - HDG	8.2 S	
	29.81 S		•		
Major Alarms	2.31 S		•		
Alarms - STB	10.0 S		•		
AP - SWN	12.5 S	4			
Status - SGT	4.8 S				
	29.61 S				

Section 3

CANDIDATE ATEC ADAPTATIONS

3.1 CANDIDATE HARDWARE ADAPTATIONS

The following ATEC adaptations were considered during the course of the study as candidates for monitoring the digital FKV communications network. Of these initial candidates, the hardware adaptations ultimately recommended for the FKV are presented in detail in Paragraph 3.2, Recommended Hardware.

3.1.1 Events Per Unit Time (EPUT)

3.1.1.1 EPUT

In the domain of digital communications, individual pieces of information are transmitted during discrete time periods. This discreteness gives rise to units of measure such as bit errors, error rate, and loss of frame synchronization.

With the exception of radio transmission, the quality of the data content of a bit stream and the health of the processing equipment is typically measured in terms of these discrete quantities.

In the general sense, knowledge of the distribution of occurrences of quantities such as bit errors is the ultimate measure of performance. In the practical sense, these distributions are characterized by their mean, such as mean error rate.

The EPUT would have the capability of interfacing with short duration (300 nanosecond) pulses and counting their occurrences over a fixed but strappable time period. The output would be a dc voltage as a function of count that could be measured by the MAC and interpreted by software.

To implement the collection of this data an adaptation of ATEC equipment is required. This adaptation can be implemented within the standard ATEC data collection scheme using the analog scanner. An Event Per Unit Time monitor (EPUT) could be used to collect format violations, frame bit errors, resynchronizations, or similar events.

The EPUT is a recommended hardware adaptation for the FKV demonstration system since a means of monitoring and counting numerous events such as frame bit errors, T1-4000 control reframes, and T1WB1 reframes has been shown to be desirable.

3.1.1.2 Event Latch

A number of events in the FKV may be of transient nature. For instance, some events such as resynchronization occur only occasionally, even under degraded conditions.

The present analog scanner does not have memory and due to the system scan rate, transient occurrences may never be observed. This problem could be avoided by providing input circuitry with latch capability such that latches are reset when scanned or a reset command is given.

These transient events could be collected using a latch that is under control of the same time base as used for the events per unit time counters. Using the same time base allows for correlation of events. The latches, which can be considered as one-bit counters, would be co-located with the event counters and would report their state as a dc voltage. The voltage would also be measured using the MAC.

The event latch is not recommended as a separate ATEC adaptation because the event-latching capability can be easily provided by an extension of the basic EPUT design.

3.1.2 Digital Baseband Monitor (Eye Monitor)

The ATEC Baseband Monitor for use in frequency division multiplexed networks measures composite baseband RMS power level, radio pilot level, and noise level in frequency slots. While these measurements could also apply to the three-level partial response radio baseband used in the FKV, much more useful information can be derived from this signal. In particular, a direct measure of signal quality that can be interpreted as a signal-to-noise ratio is possible.

In the FKV, the radio baseband signal will be in the three level, partial response format after filtering. This "eye-pattern" format is distinctive and can be quantatively evaluated for "correctness" directly, unlike FDM signals that require presumptive slot noise measurements. A monitor concept has been established which offers the direct measure of this signal and thus provides a means of assessing performance margin of the AN/FRC-162 radio and the RF portion of the FKV system. The measurement provides a predictive margin measure as well as a present-time performance measure and as a result, it is extremely useful for performance assessment as relates to the radio and RF portions of the communications link. Since the baseband monitor monitors the signal at a point between the radio receiver and the T1-4000 receiver, it is also useful for fault isolation.

The characteristic of the partial response signal which allows for such measurement is that, in the optimum, it has only three allowable levels at the sampling instant at the end of each baud. In the FKV network, the T1-4000 time division multiplexer decodes the signal into a bit stream by sampling at the end of each baud and determining which of the three levels was received. This information is combined with the state of the last bit to generate the binary state of the received bit.

In a similar manner, a monitor device could decode the baseband signal and detect received levels. Quality of this signal can be determined by measuring the deviation of the samples from the expected values. Since these deviations are a statistical quantity, any of the standard statistics measures could be derived; for example, mean and variance. The baseband eye signal-to-noise (S/N) ratio can be determined from the measured eye dispersion and knowledge of the baseband eye level. Once the S/N ratio is determined, a value for the baseband BER can be calculated using the expression for BER developed in Appendix A, Volume II.

The Baseband Monitor is therefore a candidate for adaptation to collect statistics on signal deviation. In addition, a measure of signal amplitude could also be incorporated. A more detailed discussion of concept and mechanization is given in Paragraph 3.2.2.

3.1.3 Voice Data Combiner; Error Detection

Alarm Scanner data is transmitted to the Master Alarm Display (MAD) and/or Alarm Display Unit at 75 bits/second. The transmission format was designed for intra-site communications, so that error detection appropriate for long distance transmission is not incorporated.

0376-519

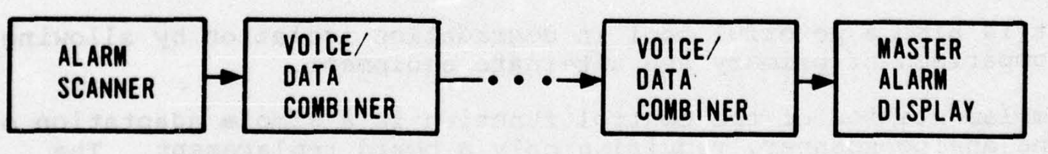

FIGURE 3-1. ALARM SCANNER DATA TRANSMISSION

Data is formated in ten-bit start/stop characters with each character separated by fifteen-bit periods. Since this format does not contain error detection capability, errors in transmission can cause erroneous interpretation of alarm states.

Physical space is available in the Voice/Data Combiner for addition of error detection circuitry. In particular, a ten-bit BCH code could be transmitted with each start/stop character utilizing ten of the fifteen-bit times between characters.

The BCH code would be stripped off at the receive Voice/Data Combiner producing the normal output format. However, characters found to contain an error would be replaced in total by the last correctly received character for those alarms.

Voice/Data Combiner error detection is not recommended as an adaptation for the FKV demonstration since only one remote telemetry link is involved and in this simple case, telemetry errors may be detected by the PATE. In the case of the entire FKV monitoring system, this adaptation is recommended since five remote to PATE telemetry links are involved. Here, the V/DC could trap bad telemetry before it is inputted to the PATE, thereby freeing the PATE for other tasks and reducing false alarms due to errors in the telemetry data.

3.1.4 DDMS 50 Kbps

Adaptation of the DDMS to monitor up to 50K bit-per-second streams would allow for monitoring all channel inputs and outputs to the T1WB1 multiplexer.

This adaptation is not considered rewarding for use in the FKV system because the 50 Kbps data streams are in station-wire pairs, which cannot introduce digital distortion.

3.1.5 Remote Control Latch

The capability of ATEC to control switching of standby equipment is a logical extension of its monitoring function; especially in networks like the FKV with standby radios and multiplexers and potentially unmanned or minimally manned sites.

This capability could be used to implement a switchover to alternate equipment to override improper action by local automatic controllers. As an example, a standby T1-4000 receiver in the FKV can be latched into operation due to a radio link fade.

It is also a powerful tool in degradation isolation by allowing comparison of primary and alternate equipment.

Implementation of the control function is a simple adaptation of the analog scanner, requiring only a board replacement. The new board would contain latching relays that could be latched or cleared through the normal analog scanner addressing scheme. These relays would provide the necessary signal for control of the switching circuits located at the effected equipment. See Paragraph 3.2.4 for implementation details.

The capability to perform remote switchover of transmission equipments under the control of the monitoring system is recommended in a full-scale FKV monitoring system implementation. However, for an ATEC/FKV demonstration, the analog scanner adaptation to permit such control is not recommended since modifications to the existing FKV radio and multiplexer equipments being controlled would be required. It is recommended that a remotely activated switchover capability be provided on future radio and multiplexer equipments used in a redundant application (such as that used in the FKV system with the AN/FRC-162 radio and T1-4000 multiplexer).

3.1.6 TSS Modification

Testing of PCM systems with a periodic test signal whose basic frequency is a submultiple of the sampling frequency can cause erroneous results. The 1 kHz test tone used in ATEC is a submultiple of the 8 kHz sampling rate used in the CY-104. This problem can be alleviated by shifting the frequency of the test signal. The following discussion presents details on the source of the anomaly.

3.1.6.1 Testing PCM Systems With Periodic Test Signals

3.1.6.1.1 Introduction

It is known that testing of PCM systems such as the TD968 and Vicom D2 by means of single frequency test tones may sometimes produce erroneous results. For example, quantizing noise may appear as harmonic distortion. This section explains a process whereby this problem may be avoided.

3.1.6.1.2 Discussion

Consider a sinusoid (or any complex, periodic test signal in general) being employed as a probe signal to test a sample data system consisting of an A/D and D/A converter. If the period of the test signal is a multiple of the sample period, or

$$NT_s = T$$

or

$$Nf = f_s ,$$

then the error signal caused by quantized sampling will also be periodic of period T. T is the input signal period and T_s is the sample period -- likewise for the frequencies f_s and f.

This relationship is illustrated in Figure 3-2.

Since the error signal due to quantized sampling is periodic of period T, it may be expressed as the Fourier series.

$$e(t) = \sum_{k=1}^{M} a_k \sin(2\ kt/T + \emptyset_k)$$

Consequently, the quantizing distortion noise occurs at discrete frequencies given by

$$f_k = 2\Pi k/T = 2\Pi kf$$

where the highest frequency in the error signal is at a frequency of

$$f_M = Mf \leq f_s/2,\ M \text{ integer}$$

or

$$M \leq N/2,\ M \text{ integer}$$

If f_s = 8000 samples per second, test frequencies leading to the above problem are:

4000 Hz	=	8000 ÷ 2
2667 Hz	=	8000 ÷ 3
2000 Hz	=	8000 ÷ 4
1600 Hz	=	8000 ÷ 5
1333 Hz	=	8000 ÷ 6
1143 Hz	=	8000 ÷ 7
1000 Hz	=	8000 ÷ 8
889 Hz	=	8000 ÷ 9
800 Hz	=	8000 ÷ 10
727 Hz	=	8000 ÷ 11
.		.
.		.
.		.

3.1.6.1.3 General Expansion

In general, the same problem due to a periodic error signal will occur if a multiple of the test signal period is a multiple of the sample period

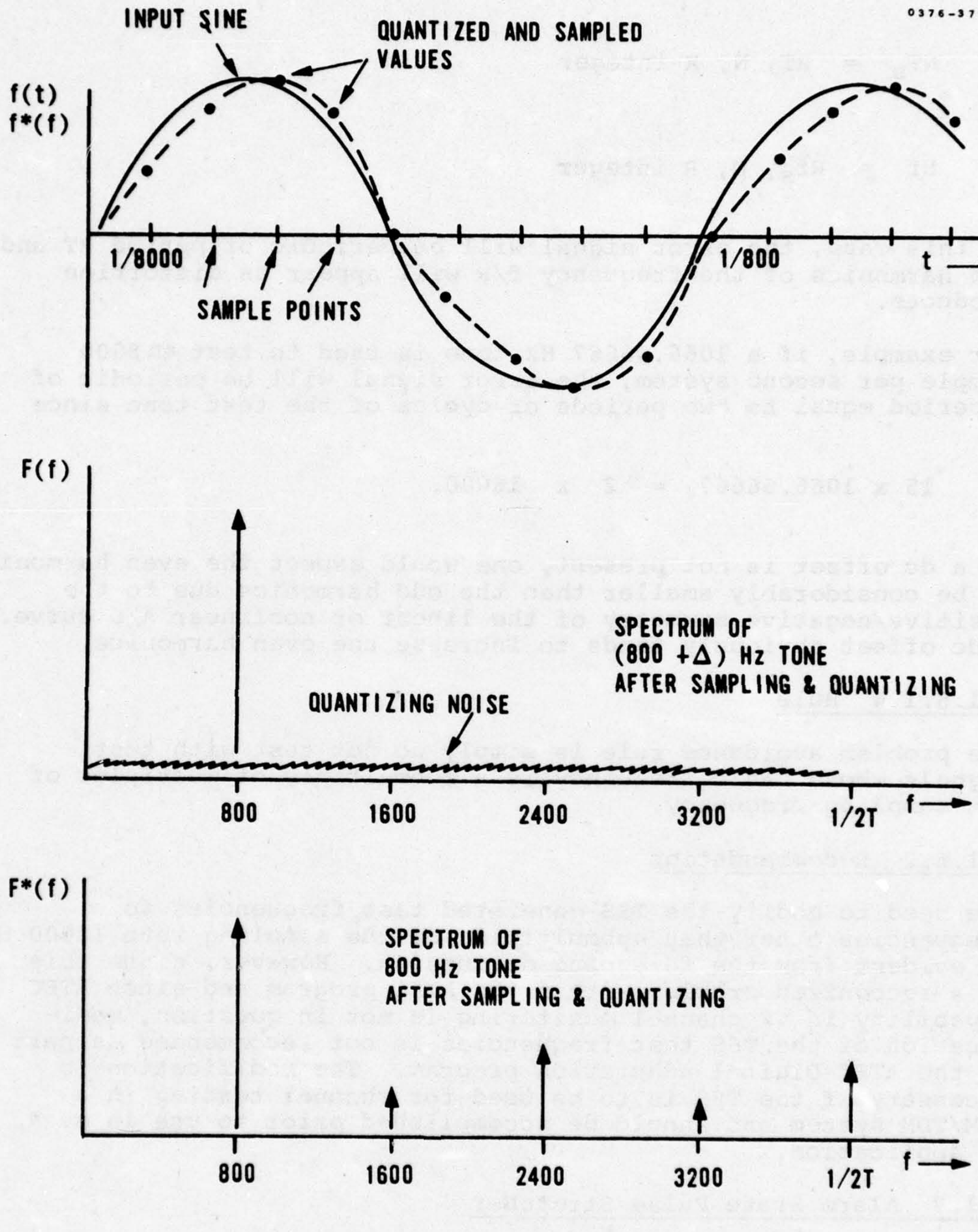

FIGURE 3-2. SAMPLING EFFECTS

or

$$NT_s = RT, \; N, R \text{ integer}$$

or

$$Nf = Rf_s, \; N, R \text{ integer}$$

In this case, the error signal will be periodic of period RT and the harmonics of the frequency f/R will appear as distortion products.

For example, if a 1066.66667 Hz tone is used to test an 8000 sample per second system, the error signal will be periodic of a period equal to two periods or cycles of the test tone since

$$15 \times 1066.66667 = 2 \times 16000.$$

If a dc offset is not present, one would expect the even harmonics to be considerably smaller than the odd harmonics due to the positive/negative symmetry of the linear or nonlinear A/D curve. A dc offset obviously tends to increase the even harmonics.

3.1.6.1.4 Rule

The problem avoidance rule is simply do not test with test signals whose basic frequency is a submultiple of multiples of the sampling frequency.

3.1.6.2 Recommendation

The need to modify the TSS-generated test frequencies to frequencies other than submultiples of the sampling rate (8000 Hz) is evident from the foregoing discussion. However, since this is a recognized problem within the ATEC program and since ATEC capability in VF channel monitoring is not in question, modification of the TSS test frequencies is not recommended as part of the ATEC Digital adaptation program. The modification is necessary if the TSS is to be used for channel testing in a PCM/TDM system and should be accomplished prior to use in such an application.

3.1.7 Alarm State Pulse Stretcher

The present alarm scanner cannot latch on alarms and only sends alarm status when the MAD is polled. With typical scan rates on the order of 3 minutes as recommended in Paragraph 2.4.3 of Volume II, transient alarm conditions are only fortuitously

observed. Excluding those alarms that relate to hard failures such as fuse and power supply, some FKV alarms are of this transient nature.

One method to stretch short duration alarms and thus guarantee recognition by the MAD and the CPU could be implemented by moidfying TTL circuitry in the alarm scanner by adding a retriggerable one-shot. A candidate circuit median system is shown in Figure 3-3. A second adaptation (see Paragraph 3.1.8) could provide the latch capability needed.

The alarm state pulse stretcher is not recommended as a candidate ATEC adaptation since the latch function is performed by the event latch portion of the EPUT.

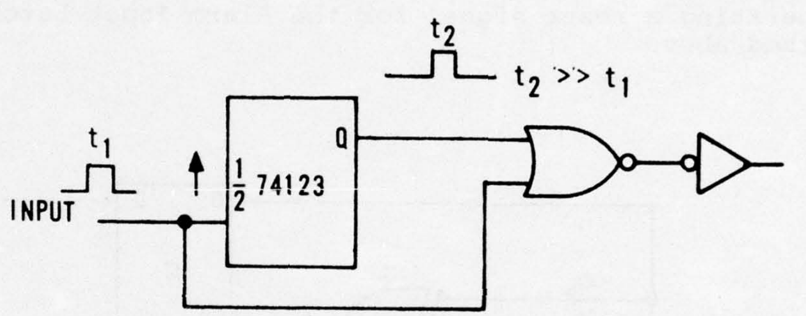

FIGURE 3-3. RETRIGGERABLE ONE-SHOT

<u>3.1.8 Alarm Input Latch Circuit</u>

The present alarm scanner does not have memory, rather the input state of a given alarm is read only at a specific instant during which that particular alarm is sampled and encoded into an Alarm Scanner output for transmission to a MAD or Alarm Display. If a transient alarm occurs between the times the given alarm is read out to the MAD or AD, the transient will not be observed by the monitor system. Use of an alarm input latch circuit modification would solve the problem and, additionally, permit the system alarm scan rate to be a software selectable variable.

This modification would provide all alarm input circuitry with latch capability such that latches are reset when alarms are scanned or a reset command is given.

The AS modification would entail adding the TTL circuitry illustrated in Figure 3-4 to each alarm input. The circuit operates as follows: A low-frequency (50 Hz) clock pulses D-type flip-flops A and B through Gate F. If the input alarm to flip-flop A changes state,exclusive OR Gate E goes positive 1/50 second later and clocks the new state into output flip-flop C. Flip-flop B then changes state and Gate E goes to zero, clocking flip-flop D switching its output to zero which inhibits the clock from going through NAND gate F, thereby freezing the circuit from any further activity. Once the output alarm state has been sampled or read out, the circuit is reset through an external source reset signal to flip-flop D. The reset signal returns flip-flop D to a 1 state, thus allowing the clock pulse to pass through Gate F.

A modification to the MAD would be required to provide a means of generating a reset signal for the Alarm Input Latch circuit described above.

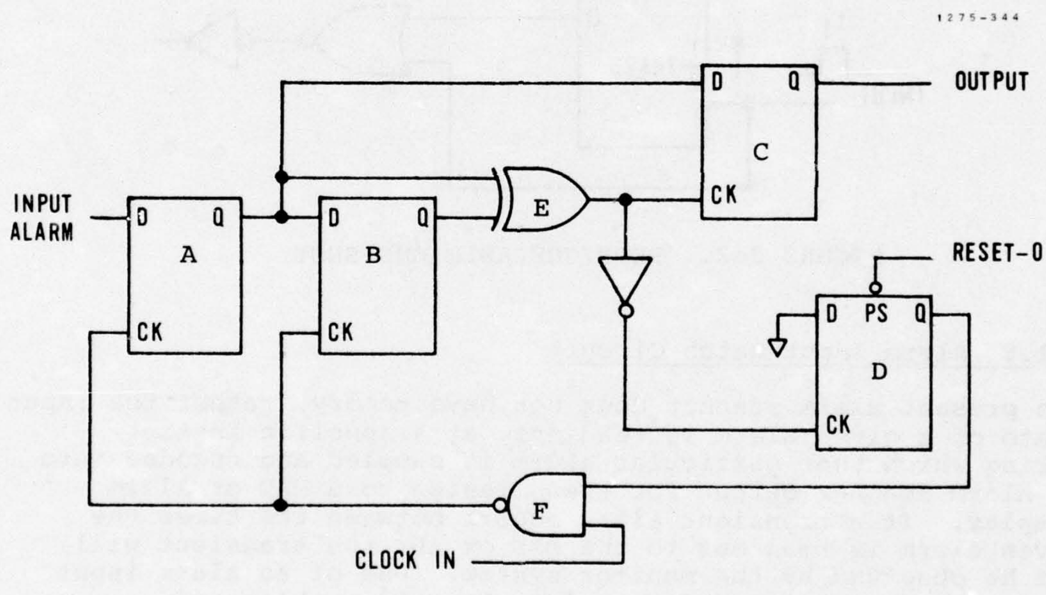

FIGURE 3-4. ALARM INPUT LATCH CIRCUIT

The Alarm Input Latch modification is not recommended for FKV use since its function is performed by the event latch portion of the EPUT.

3.1.9 Digital Signal Activity Sensor

A means to convert inactivity of a digital signal to a TTL alarm output is desirable for use with T1-4000 inputs and outputs; T1WB1 T1 inputs and outputs and channel inputs and outputs.

This Digital Signal activity Sensor would trigger alarms upon loss of T1 signals. Knowledge of input and output signal activity helps considerably in equipment fault isolation.

This detection capability can be provided by constructing a converter for each desired signal as illustrated in Figure 3-5. The circuit is composed of an input-level shifter or buffer stage and a TTL retriggerable one-shot multivibrator. If the one-shot period is one to two orders of magnitude longer than the period of a data bit, data activity periodically retriggers the one-shot before the base time period expires. Hence, the one-shot output remains high or a logic 1. If the data activity disappears, the one-shot output will return to zero at the end of the one-shot period. A zero at the output, therefore, indicates a loss of data activity.

The converter may or may not be self-contained and may derive power from the alarm scanner.

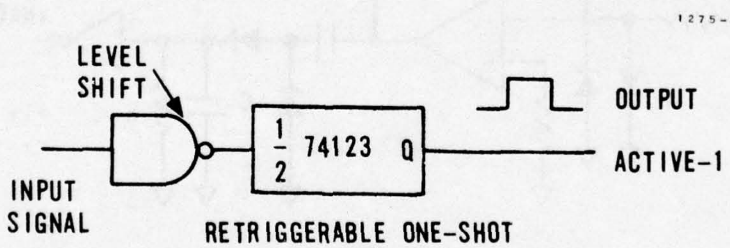

FIGURE 3-5. DIGITAL SIGNAL ACTIVITY SENSOR

This adaptation is not recommended for the FKV monitor system since data interfaces were rejected as monitor points in Paragraph 3. 8 of Volume I.

3.1.10 Analog Signal Activity Sensor

Similar to the digital activity sensor described in Paragraph 3.1.9, an analog signal activity sensor would also offer assistance in equipment fault isolation.

Providing a means to convert the inactivity of an analog signal into an alarm condition would be needed at T1-4000 analog outputs and inputs.

The sensor could be implemented by construction of a converter for each desired signal as illustrated in Figure 3-6. The input signal is ac coupled and then clipped by the two diodes before amplification by the operational amplifier. The amplifier output is then rectified causing capacitor C to be charged to a positive voltage if an ac signal is present at the sensor input. The positive capacitor voltage causes a logic 0 at the sensor output. If the input signal disappears, the capacitor C is discharged by resistor R causing a logic 1 at the output. The converter may or may not be self-contained and may or may not derive power from the alarm scanner.

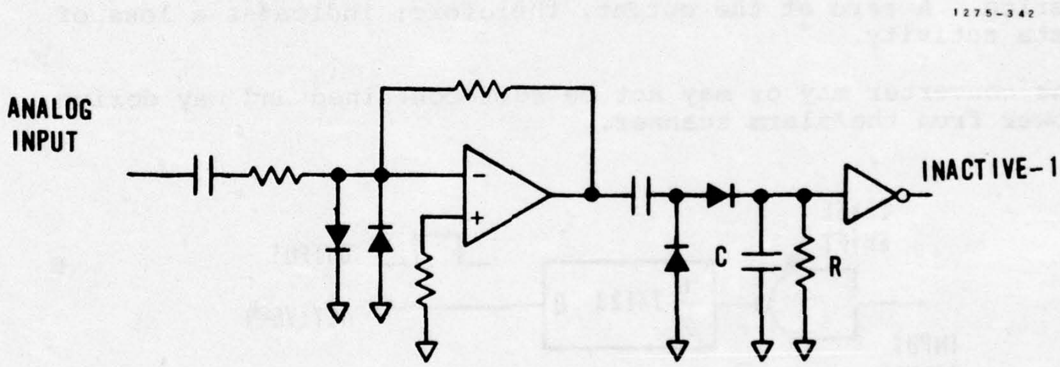

FIGURE 3-6. ANALOG SIGNAL ACTIVITY SENSOR

This adaptation is not recommended for the FKV monitor system since data interface signals were rejected as monitor points in Paragraph 3.8 of Volume I.

3.1.11 DC Voltage-Level Sensor

Detection of a degraded power supply before failure can be useful for failure prevention. This can be done by using the MAC to measure the analog voltage. An alternate method is to develop a dc voltage-level sensor which provides an alarm output when a dc voltage deviates a predetermined percentage from nominal. It could be employed for all equipment power supply voltages which are accessible.

A candidate voltage sensor circuit which alarms when the input goes out of range is illustrated in Figure 3-7. The circuit develops a reference voltage E by means of a constant current through the Zener diode. The voltage E is divided down to a voltage $V-\Delta$ at the input to comparator C1 where V is the nominal (correct) value of the input voltage and Δ is the maximum allowable deviation of the input from nominal, approximately 0.25 volts. If the input voltage is less than $V-\Delta$, the output of C1 becomes positive and causes a logic 0 at the NOR gate output which indicates an out-of-tolerance input voltage. Similarly, E is also divided to yield a voltage of $V + \Delta$ at the negative input of comparator C2. If the input voltage exceeds $V + \Delta$, the output of C2 becomes positive and causes a logic 0 at the NOR gate output.

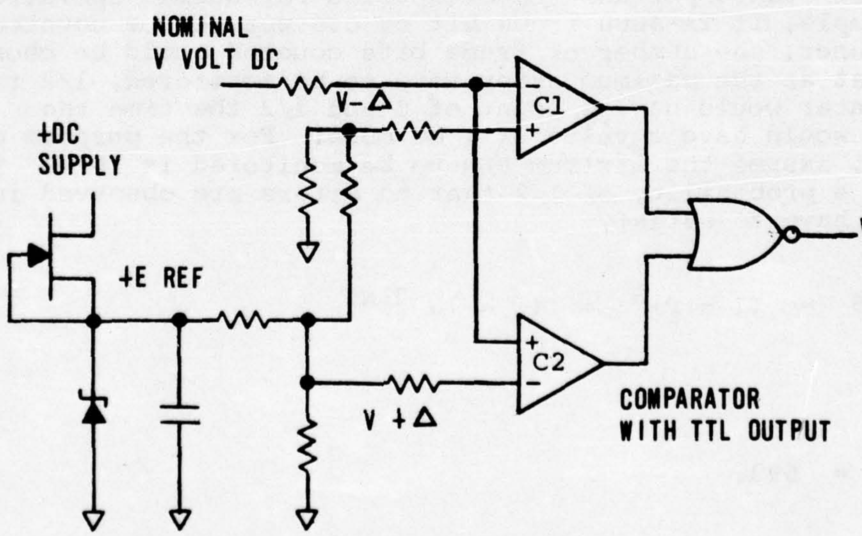

FIGURE 3-7. VOLTAGE SENSOR CIRCUIT

The voltage sensor circuit adaptation is not recommended for use in the FKV monitoring system since dc voltage levels are more easily monitored by means of MAC voltage measurements.

3.1.12 Single-Bit Parameter Counter

The present MAC cannot accept,as inputs, parameters that are in the form of multiple-bit digital data words. It can only measure or accept ac or dc voltages. An adaptation that is feasible which provides a means of measuring events per unit time when only one bit data encoding is possible and when the sample rate is slow compared to the time to measure only one event.

Within the FKV network, this adaptation would serve to measure numerous equipment parameters. This would include:

T1-4000 3-level violations, main frame bit errors, main reframes

T1WB1 reframe, frame bit errors and error check

CY-104 restarts

AN/FRC-162 squelch.

One method of accomplishing the task would be to count events for only a small fraction of the time between expected sample times and to set the counting period such that the expected number of counts during this period is 1/2 for the maximum number of events per unit time expected for normal operation. For example, if T1-4000 frame bit errors were to be counted in this manner, the number of frame bits counted would be chosen such that at the maximum error rate to be monitored, 1/2 time the counter would have a count of 0 and 1/2 the time the counter would have a value of 1 or more. For the purpose of this example, assume the maximum BER to be monitored is 10^{-3}. Then to have a probability of 1/2 that no errors are observed in N bits, N would have to satisfy

$$0.5 = (1 - P)^N = (1 - 10^{-3})^N$$

or

$$N = 693.$$

Therefore, the counter would count the frame bit errors over an interval of 693 frame bits and then stop counting. One-half the time the counter would have a value of 0 and 1/2 the time the counter would have a value of more than 0. Without much loss of information (since 1/2 the time the counter output is 0) the counter output may be restricted to the values 0 and 1, thereby, the term Single-Bit Parameter Counter.

Since the counter output is limited to the values 0 and 1, it may be measured as a two-valued variable by a device such as an Alarm Scanner.

A key concept associated with the counter as applied to ATEC modification is that the time that the counter is actively counting is significantly less than the time during which the counter is held constant, with its count locked after counting. For example, return to the counting of T1-4000 frame bit errors over an interval of 693 bits. Counting 693 T1-4000 frame bits would require

$$\frac{693 \text{ bits}}{96.9\text{K bits/second}} = 7.2 \text{ milliseconds}$$

For a counting period of 7.2 ms, a reasonable choice of lock-up period would be $T = 100 \times 7.2 \text{ ms} \approx 1$ second. Hence, the counter would count for 7.2 ms and be locked for 1 second. If the counter is sampled asynchronously, the probability of sampling the counter during the counting period is

$$P = 7.2 \text{ ms}/(1 \text{ second} + 7.2 \text{ ms}) \approx 7.2 \times 10^{-3}$$

or is negligibly small.

A block diagram of a candidate parameter counter mechanization is shown in Figure 3-8. The adaptation permits parameters to be measured with data transferred as an alarm status. It demands only simple hardware to measure parameters and permits parameters to be sampled asynchronously.

As a second example, suppose the monitor output would be scanned every $T = T_1 + T_2$ seconds average, as shown in Figure 3-9. As an example, consider T1WB1 frame bit errors at 8000 frames/seconds.

We want T_1 to be such that P(1 or more errors) = P(0 errors) = 1/2 at an error rate of 10^{-5}; i.e., we get no errors in T_1

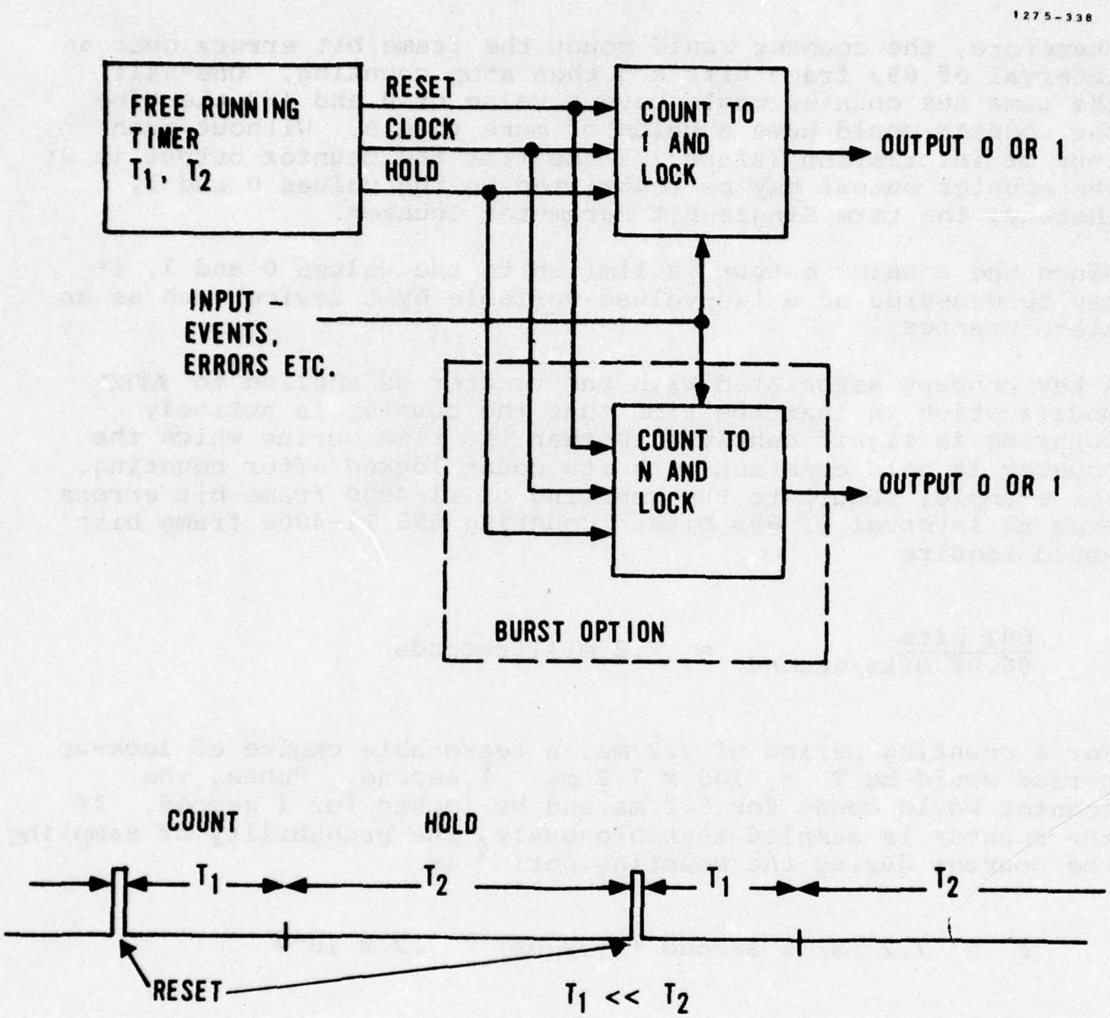

FIGURE 3-8. PARAMETER COUNTER

one-half the time:

$$0.5 = P(0 \text{ errors}) = (1 - P)^N = (1 - 10^{-5})^N$$

$$N = \log 0.5/\log (1 - 10^{-5})$$

$$= 6.9 \times 10^4 \text{ Framing Bits}$$

$$T_1 = N/8000 = 8.7 \text{ seconds}$$

make T_2 = 51.3 seconds.

It can be shown that expected number of errors is actually 0.46 instead of 0.5 since the unit may sample output during T_1 instead of T_2.

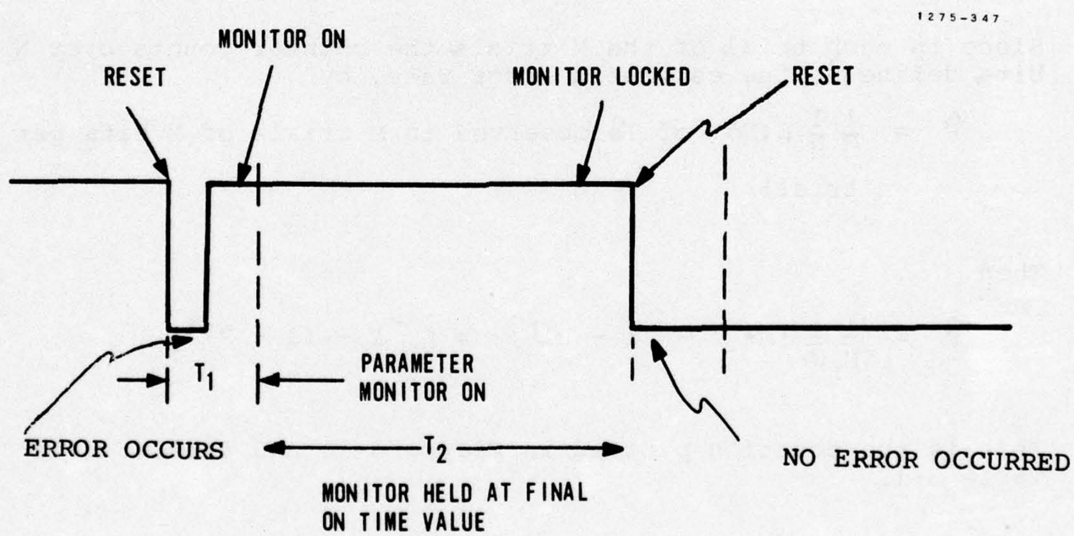

FIGURE 3-9. SAMPLE PARAMETER ALARMS

Table 3-1 presents the number of observed errors versus number of monitored bits and bit error rate. Figure 3-10 presents the saturation effect of observed error rate versus actual error rate for various sized groups of monitored bits.

Analysis of the parameter counter is as follows. Define P as the actual bit error probability. Define N as the number of bits counted before the counter is locked at a count of 0 or 1. Define M as the number of times the counter is read out.

In M trials or readings, the expected number of 1's observed is

$$
\begin{aligned}
E\ (\text{No. of 1's}) &= M^*(\text{Probability of a count of 1 or greater in one trial}) \\
&= M^*(\text{Probability number of errors is 1 or greater}) \\
&= M^*\left[1 - (\text{Probability number of errors is 0})\right] \\
&= M^*\left[1 - (1 - (1 - P)^N\right].
\end{aligned}
$$

Since in each trial, of the M trials, the counter counts over N bits, define $\hat{P}$, the estimated error rate, by

$$\hat{P} = \frac{1}{M}\frac{1}{N}\, E(\text{No. of 1's observed in M trials of N bits per trial})$$

Then

$$\hat{P} = \frac{1}{M}\frac{1}{N}\left\{M^*\left[1 - (1 - P)^N\right]\right\} = \frac{1}{N}\left[1 - (1 - P)^N\right].$$

This is the equation plotted in Figure 3-10 and tabulated in Table 3-1.

TABLE 3-1. MEAN OBSERVED OCCURRENCES

1275-3268

P (PROBABILITY OF ERROR)	N, NUMBER OF BITS MONITORED: 10	10^2	10^3	10^4	10^5	10^6
0.5	0.999	1.000				
0.1	0.651	1.000				
10^{-2}	0.096	0.631	1.000			
10^{-3}	0.010	0.095	0.631	1.000	1.000	
10^{-4}	0.001	0.01	0.95	0.631	1.000	1.000
10^{-5}	10^{-4}	0.001	0.01	0.095	0.631	1.000
10^{-6}	10^{-5}	10^{-4}	10^{-3}	0.01	0.095	0.631
10^{-7}	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	0.095
10^{-8}	10^{-7}	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}

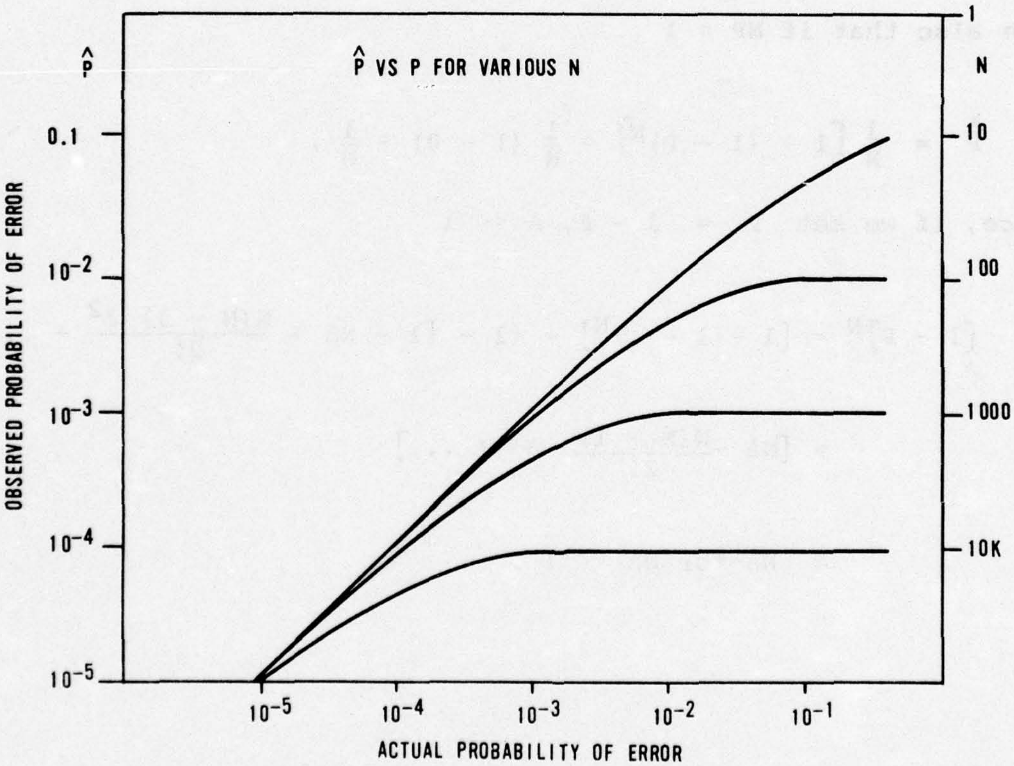

FIGURE 3-10. SINGLE BIT EVENT COUNTER SATURATION

Note that, if $NP << 1$,

$$\hat{P} = \frac{1}{N}\{1 - [1 - NP + \frac{N(N-1)P^2}{2!} - \dots]\}$$

$$\simeq \frac{1}{N}\{NP - \frac{N(N-1)P^2}{2!} + \dots\}$$

$$\simeq \frac{1}{N} NP$$

and

$\hat{P} \simeq P$ for $NP << 1$.

Note also that if $NP \simeq 1$

$$\hat{P} = \frac{1}{N}[1 - (1 - P)^N] \simeq \frac{1}{N}(1 - 0) \simeq \frac{1}{N},$$

since, if we set $P = 1 - \Delta$, $\Delta << 1$

$$[1 - P]^N = [1 - (1 - \Delta)^N] = \{1 - [1 - N\Delta + \frac{N(N-1)}{2!}\Delta^2 - \dots]\}$$

$$= [N\Delta - \frac{N(N-1)}{2!}\Delta^2 + \dots]$$

$\simeq N\Delta$ for $N\Delta << 1$.

Specifically,

$$\lim_{P \to 1} (1 - P)^N = \lim_{\Delta \to 0} |1 - (1 - \Delta)|^N \to 0 .$$

Hence, for NP << 1

$$\hat{P} \simeq P$$

While for NP $\simeq$ 1

$$\hat{P} \simeq \frac{1}{N}$$

This explains the saturation effects of the curves shown in Figure 3-10.

The parameter counter is not recommended as a candidate ATEC adaptation for FKV implementation since its function is more efficiently and more accurately performed by the event per unit time (EPUT) monitor which was previously discussed.

3.1.13 MAD Alarm Time Tag

This adaptation would permit time correlation of received alarms while utilizing present ATEC equipment. The change involves the incorporation of a real time clock in the MAD. When a major alarm occurs, time is read into the storage register. When queried time is read out in response, and register contents are cleared. The adaptation would permit isolation of causes of transient type disturbances since time correlation of events or alarms would be known. Application of the scheme would be throughout the FKV monitoring system especially with alarms of transient character.

The alarm time tag adaptation is not recommended for use in the FKV monitoring system for several reasons. First, the origin of transients may be determined from a top-down analysis of the resultant alarm indications. Secondly, use of multiple bit time tags would significantly increase the telemetry data rate and the PATE input/output rate as well as increase the software processing time devoted to alarm data. Third, the adaptation would require a major modification of the MAD circuitry.

3.1.14 MAD "Any Alarm" Encoding

The MAD presently receives "any alarm" status from alarm scanners for front-panel display. A possible adaptation to the MAD would be to modify it so that it may be queried for change of state or occurrence of any alarm in addition to being queried for major alarm occurrence.

Without this feature, all minor alarms must be periodically scanned by the PATE, thereby consuming telemetry channel capacity and central processor time. With this feature, alarms would not be scanned unless an alarm state were known to exist in a particular scanner. The change would be applicable to all system alarms which are not defined as major alarms.

The "any alarm" encoding is not recommended as an ATEC adaptation for FKV use since all alarms are scanned as part of the normal monitor system scan sequence. As detailed in Paragraph 2.5, Volume III, Table 2-3, alarm scanning only requires 31% of the total scan time and a hardware modification to reduce this percentage is not warranted.

3.1.15 Error Rate Monitor

An Error Rate Monitor adaptation could provide a means of measuring bit error rate, end-to-end, on out-of-service or unused channels. The technique would involve the transmission of a known pseudo random sequence on the unused channel and a check sequence for errors at the receiver. It would permit a direct measure of user-to-user error rate as opposed to the presumptive measure of error rate based upon equipment parameter monitoring.

Application would be on unused digital channels in FKV, specifically one channel between each site where a breakout is possible. For example, HDG to KSL, HDG to VHN and SGT to VHN.

Figure 3-11 depicts a possible mechanization of the function based upon the use of pseudo random sequence generation (PRG). Since the test is out of service, a pseudo random sequence is fed to the channel input. At the receive end, an identical sequence is generated and synchronized to the sequence at the channel output. For a fixed number of bit times, N, these sequences are compared and differences or errors are counted. The error count divided (in software) by the known number of elapsed bits, N, gives the observed BER.

This adaptation is not recommended for FKV use since it requires that the channel be placed out of service for the test period. Additionally, a value for the digital link BER may be obtained by the recommended EPUT adaptation which does not require that any data channels be taken out of service.

3.1.16 Error-Free Second Counter

A new MAC/MAD option, similar in construction to error rate monitor could be implemented as an add-on to the error rate monitor described in Paragraph 3.1.15. This change would measure end-to-end error-free seconds on unused channels for the purpose of system performance data generation. This would provide important statistical information related to system management performance monitoring and also to performance of the system as seen by user. The counter would be employed on unused channels within the FKV, particularly on end-to-end links.

The error-free second counter is not recommended as an adaptation for FKV use since it requires that the channel be out of service for the test period.

3.1.17 MAC Telemetry Rate Increase

An increase in the telemetry rate from MAC to PATE will decrease the time required to detect equipment degradation in the FKV. To provide a greater data rate capacity from MAC to processor-telemetry channel, the MAC could be modified to change output rate from 150 bps to 300 bps or 600 bps. Performance increase derived through use of a multi-channel telemetry system is analyzed in the following discussion.

3.1.17.1 Alternate Telemetry Configurations

As a means of decreasing the monitoring system scan times, two improved telemetry schemes may be postulated. Both approaches attempt to reduce the scan time by reducing the time required to

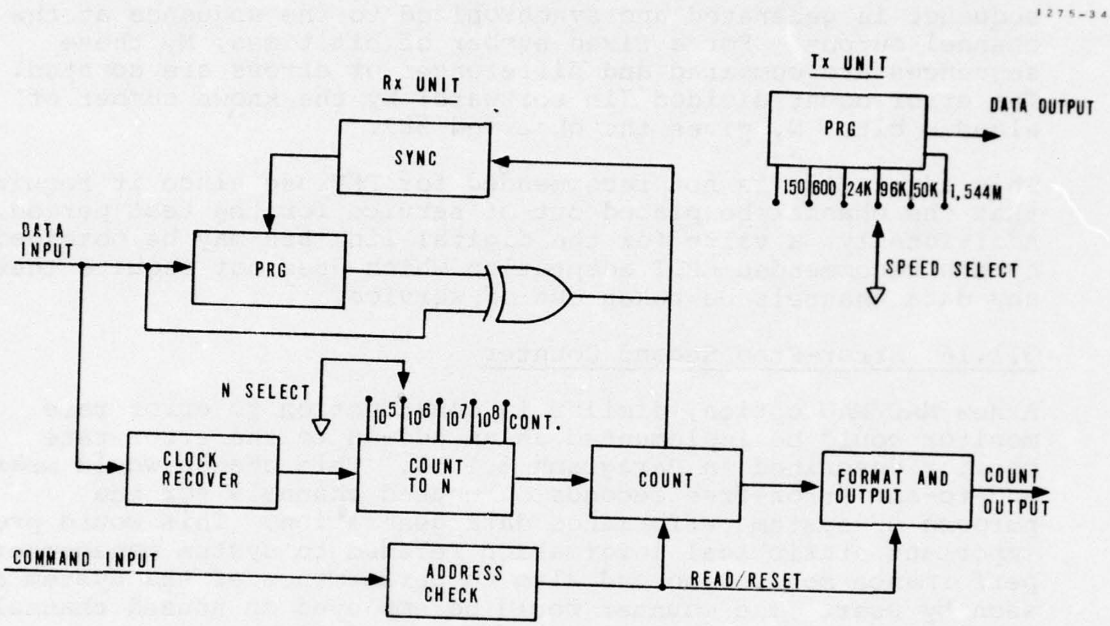

FIGURE 3-11. ERROR RATE MONITOR

interrogate a MAC and options (or MAD) and receive a response.

The approach illustrated in Figure 3-12 employs a 600 bps channel for PATE and MAC communication as opposed to the normal 150 bps link. This requires a MAC/MAD/PATE adaptation to accommodate the increased bit rate. This adaptation involves increasing the MAD, MAC and PATE clock rates by a factor of 4 and modifying the internal logic of these devices to accommodate the higher clock rate. The scan cycle times for this configuration shown in Table 3-2 are explained as follows:

ALARMS

If the telemetry rate is 150 baud, 10 seconds are required to read 50 alarms. The 10 seconds are composed of 5.7 seconds AS to MAD delay and 4.3 seconds for PATE to MAD, MAD to PATE data transfer. Increasing the telemetry rate to 600 baud decreases the data transfer time to 1.07 seconds ($4.3 \div 4$). Since AS to MAD rate remains at 75 baud, the AS to MAD delay remains 5.7 seconds and the time required to retrieve the status of 50 alarms becomes 6.8 seconds ($5.7 + 1.07$).

ANALOG AND DIGITAL PARAMETERS INCLUDING MAINTENANCE PARAMETERS

The time required to scan analog, digital and maintenance-related analog parameters does not decrease if the telemetry date rate is increased from 150 to 600 baud. The time is totally used as the actual time required by the MAC hardware to measure the dc voltage in the sequential scan mode. In the sequential scan mode, during the 2.5 seconds "N" measurement is being made, data from the preceding measurement, "N-1," is being transferred from the MAC to the PATE. Hence, the scan time per monitor point is not a function of the telemetry rate.

STATUS

The same rationale applied to the Alarms discussion above applies to status parameters.

MAJOR ALARMS

Major alarms would be scanned four times as fast at 600 baud, than at 150 baud. Since each MAD output character contains a major alarm bit, the character rate is increased by a factor of four.

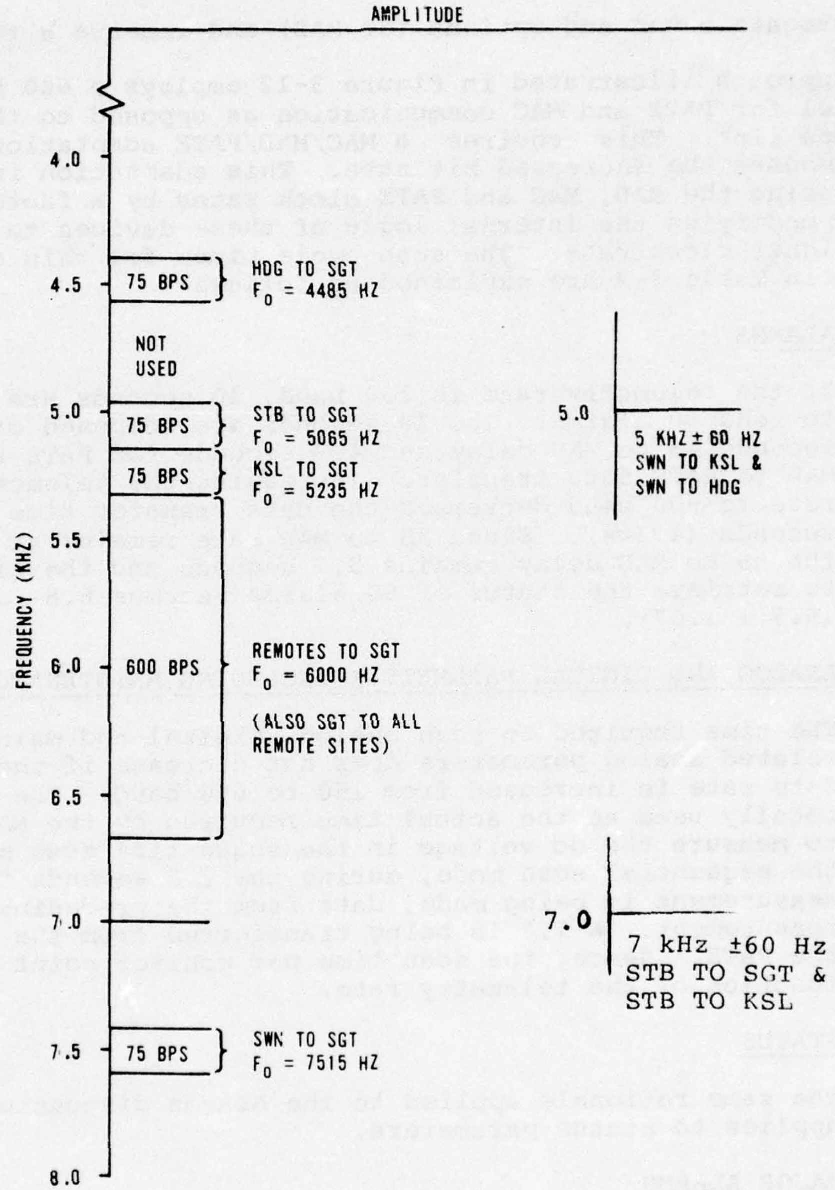

FIGURE 3-12. OPTIONAL 600 BPS TELEMETRY TO/FROM MACs

TABLE 3-2. FKV SYSTEM SCAN ANALYSIS

PARAMETER TYPE	FREQ. REQT: NO. OF TIMES/ DAY/(CYCLE)	SITE	600 BPS SINGLE CHANNEL TELEMETRY ABSOLUTE TIME PER CYCLE	ABSOLUTE TIME PER 30 SECONDS
Alarms	480/(3 Min)	HDG	5.5 S	
		SWN	5.5 S	
		KSL	6.8 S	
		STB	6.8 S	
		SGT	6.8 S	
		VHN	5.5 S	
			36.9 Total	6.15 Sec
A&DP	96/(15 Min)	HDG	45 S	
		SWN	55 S	
		KSL	80 S	
		STB	80 S	
		SGT	90 S	
		VHN	45 S	
			395 Total	13.17 Sec
Status	288/(5 Min)	SGT	4.0 Total	0.40 Sec
AP/M	4/(6 Hr)	HDG	47.5 S	
		SWN	40 S	
		KSL	65 S	
		STB	65 S	
		SGT	95 S	
		VHN	47.5 S	
			360 Total	0.50 Sec
Major Alarms	2880/ (30 Sec)	HDG	.08 S	
		SWN	.08 S	
		KSL	.08 S	
		STB	.08 S	
		SGT	.17 S	
		VHN	.08 S	
			0.57 Total	0.57 Sec
IQCS Test	2880/ (30 Sec)		4.0 Total	4.0 Sec
MAC Test	24/(1 Hr)		15.0 Total	0.13 Sec
Total Time Required Out Of 30 Seconds				24.92 Total

$$\frac{\left(\text{Scan Freq. Per Day}\right)\left(\text{Scan Time In Seconds}\right)}{1440\ \text{Minutes}} \div 2 = \text{Absolute Time per 30 seconds}$$

IOCS AND MAC SELF-TEST

The time required for these self-tests are not dependent on telemetry rates and require as much time at 600 baud as at 500 baud. In terms of the proposed 150 bps scan budget which requires 29.65 seconds out of 30 seconds (as shown in Table 2-3 of Volume III) the increased telemetry scan time requirement is 24.92 seconds as detailed in Table 3-2. Thus a net reduction in time consumed of 16 percent is attained.

A second approach to reducing the consumed scan time entails using multiple 150 bps input lines from the remote MACs to the PATE as shown in Figure 3-13. One 150 baud channel connects VHN to SGT. One 150-baud party line connects the MACs at HDG, SWN, KSL and STB to SGT.

The number of parameters scanned by means of the 150-baud telemetry channel to HDG, SWN, KSL and STB exceeds the number at SGT or VHN and this telemetry channel becomes the limiting factor in system scanning. All the parameters at SGT or VHN may be scanned in less time than those at HDG,SWN, KSL and STB. Therefore, the absolute time per cycle is given by the sum of the absolute times required to scan all parameters of a given type at HDG, SWN, KSL and STB. For example, the absolute time to scan all alarms is 8.2 + 8.2 + 10.0 + 10.0 = 36.4 seconds. A similar example may be applied to other parameter types.

An FKV scan analysis for the 150-baud multiple channel telemetry system is given as Table 3-3. As shown, the system scans the FKV in 20.49 seconds out of total of 30 seconds available. When compared to the normal system scan time of 29.65 seconds as detailed in Section 2.5 of Volume III, Table 2-3, a 31 percent improvement is obtained.

Due to the only modest improvements attained compared to the complexity incurred by increasing the telemetry rate, these system modifications are not recommended for further investigation or implementation.

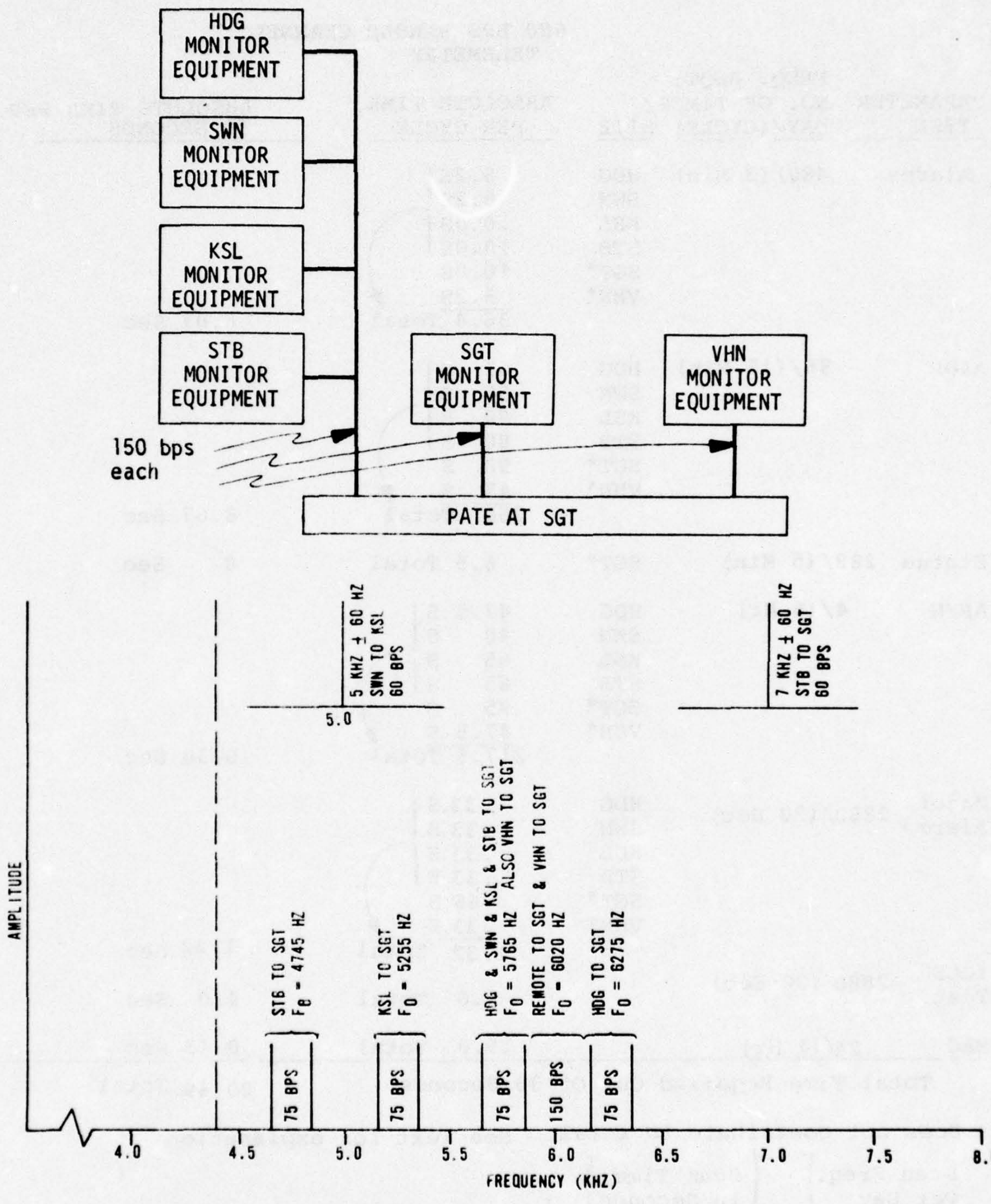

FIGURE 3-13. TELEMETRY - REMOTE SITES TO SGT, MULTI MAD CHANNELS

TABLE 3-3. FKV SYSTEM SCAN ANALYSIS

PARAMETER TYPE	FREQ. REQT: NO. OF TIMES/ DAY/(CYCLE)	SITE	600 BPS SINGLE CHANNEL TELEMETRY ABSOLUTE TIME PER CYCLE	ABSOLUTE TIME PER 30 SECONDS
Alarms	480/(3 Min)	HDG	8.2S	
		SWN	8.2S	
		KSL	10.0S	
		STB	10.0S	
		SGT*	10.0S	
		VHN*	8.2S	
			36.4 Total	6.07 Sec
A&DP	96/(15 Min)	HDG	45 S	
		SWN	55 S	
		KSL	80 S	
		STB	80 S	
		SGT*	90 S	
		VHN*	45 S	
			260 Total	8.67 Sec
Status	288/(5 Min)	SGT*	6.5 Total	0 Sec
AP/M	4/(6 Hr)	HDG	47.5 S	
		SWN	40 S	
		KSL	65 S	
		STB	65 S	
		SGT*	95 S	
		VHN*	47.5 S	
			217.5 Total	0.30 Sec
Major Alarms	2880/(30 Sec)	HDG	.33 S	
		SWN	.33 S	
		KSL	.33 S	
		STB	.33 S	
		SGT*	.66 S	
		VHN*	.33 S	
			1.32 Total	1.32 Sec
IQCS Test	2880/(30 Sec)		4.0 Total	4.0 Sec
MAC	24/(1 Hr)		15.0 Total	0.13 Sec
Total Time Required Out Of 30 Seconds				20.49 Total

* Does not contribute to total. See Text for explanation

$$\frac{\left(\text{Scan Freq. Per Day}\right)\left(\text{Scan Time In Seconds}\right)}{1440\ \text{Minutes}} \div 2 = \text{Absolute Time per 30 seconds}$$

3.2 RECOMMENDED HARDWARE ADAPTATIONS FOR FKV NETWORK

Of the candidate ATEC hardware adaptations presented in Paragraph 3.1, four are recommended for monitoring the FKV network. These are the Events Per Unit Time monitor (EPUT), the Digital Baseband Monitor (eye pattern), the Voice/Data Combiner Telemetry Error Control, and the Remote Control Latch. The Remote Control Latch, however, is not recommended for the FKV demonstration due to the need of significant modifications to the communications network for complete implementation of remote control.

3.2.1 Event Per Unit Time (EPUT) Monitor and Latch

Collection of error rate information from the Time Division Multiplexers used in the FKV requires summing pulses from multiplex equipment. This summing function is not currently available in the Analog Scanner. As discussed in Paragraph 3.1.1, this capability can be realized via the addition of new circuit boards to the Analog Scanner which will measure event rate and latch transient digital events.

Functional requirements established for the EPUT and Latch adaptation include:

1. Count the number of events over a variable time base and output a dc voltage as a function of rate.
2. The time base shall be field strappable at four minutes or less.
3. A full scale indication shall be given if overflow occurs.
4. Event rates of approximately 10^{-3} events per T1-4000 frame bits shall be measured without overflow.
5. Input digital pulses shall be 324 nanoseconds or more in width.
6. Latch transient digital events.
7. Clear latches and event rate counter at same time.
8. Output dc voltage to indicate state of latch.

A brief discussion of basis for each of the requirements and implementation detail for the EPUT follows.

3.2.1.1 Requirements for the EPUT Adaptation

1. Count the number of events over a fixed time base and output a dc voltage as a function of event rate.

   By reporting an event count over a fixed time base, the time of collection does not have to be reported as data and, therefore, minimizes time of data collection.

   For simplicity, it is recommended that the EPUT be an adaptation to the analog scanner which normally interfaces with the dc voltage meter of the MAC. Therefore, a dc voltage format for the data is appropriate.

2. The time base should be field strappable at four minutes or less in 1/2 minute increments.

   The length of time events are to be collected for generating a single data point should be related to the amount of time between queries by the computer. The rate of updating the output dc voltage should be slightly faster than the normal scan rate so that fresh data is always available. To allow for variations in scan rate due to system size, a strappable time base is desirable.

3. Event rates of approximately 10^{-3} and less should be measured with overflow.

   The purpose of EPUT is to detect degraded operation. Therefore, it is required that event rates be quantified accurately under degraded operation. Saturation of event rate measurement in the region of 10^{-3} allows quantifying very badly degraded operation and, therefore, is more than adequate.

4. A full scale indication should be given if overflow occurs.

   With this provision, qualification of event rate can be bounded and operation categorized as extremely degraded. At this level of event rate, such categorization is quite adequate.

5. Accept digital input pulses of 324 nanoseconds or more in width at a rate of 9.65×10^4 PULSES/SECOND or less.

   The highest rate signal to be collected in the FKV is main frame bit miscompares from the T1-4000. Main framing bits occur at a rate of 9.65×10^4 bits/second.

   The shortest pulse width to be monitored is the T1WB1 framing bit error signal that has a width of 324 nanoseconds.

6. Latch transient digital events.

   Knowledge of transient occurrences are important to proper interpretation of other collected data, as well as to proper interpretation of network performance in general. An an example, transient loss of T1-4000 main frame synchronization will drastically effect T1-4000 main frame error counts thus significantly altering interpretation of this anomoly.

7. Load output buffers for latches and event rate counters at the same time.

   The purpose of this is to report data taken simultaneously to provide for event correlation as described above.

8. Output dc voltage to indicate state of latch.

   Basis for this data reporting format is the same as for the event counters.

3.2.1.2 Implementation

A block diagram of the approach to satisfy these requirements is given in Figure 3-14. Two new circuit board types are shown. The timing and control function will be located on one board; the second board type will contain one event counter and three latches with external interfaces.

A separate event counter board must be dedicated to each signal to be counted; however, only one time base board is needed per analog scanner. In this manner, time correlation between all counts and latches is assured.

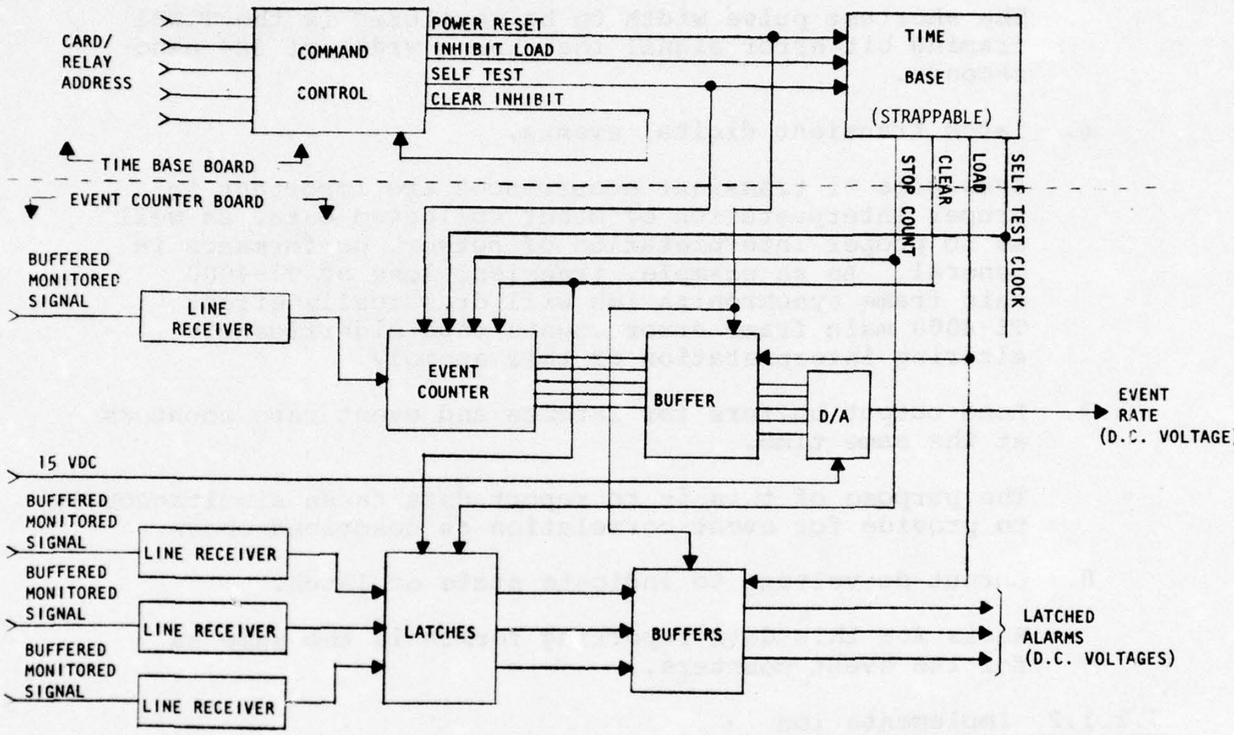

FIGURE 3-14. EPUT IN ANALOG SCANNER

Short duration monitored pulses will be transmitted to the EPUT using a differential line driver located physically close to the monitored signal and received at the EPUT using a differential line receiver. It is desirable to mount the line driver in the monitored equipment, preferably on the circuit board generating the pulse. If this cannot be accomplished, the driver should be located on the chassis of the monitored equipment. Similar interfacing will be used for the event counter and latches.

Data will be collected by the event counter and latches over a period of time set in the time base. Following collection, the data will be transferred to output buffers. The counter and latches will then be cleared and data collection will restart. While new data is being collected, the buffered data will be available to the MAC. The count buffer drives a digital to analog converter which supplies the coded dc voltage output. Latch output will be standard TTL logic levels. Upon the completion of collection of a new set of data, the process will repeat.

In addition to the time base and control signals to implement the above sequence, the time base board is capable of receiving three commands. These are Self Test, Inhibit Buffer Load, and Clear Inhibit. The mechanism for commanding the EPUT is to actuate a relay closure on the time base board as would be done in a normal scan sequence. A relay closure will not occur, but the command to do so will elicit one of the three responses depending upon the relay location addressed.

The function of Inhibit Buffer Load command is to allow collection of data from all latches and counters under control of the time base without the possibility of having the buffers updated during the collection process. This insures that all of the data corresponds to the same time period and thus can be correlated. The command is not required for operation and can be bypassed if desired simply by not issuing it.

The Clear Inhibit command is the provision to again allow update of the buffers. A normal scan of EPUT data would begin with the inhibit buffer load address and end with clear inhibit address.

It should be noted that, during an inhibit, normal data collection continues. Only when the time base attempts to activate the buffer load process does the inhibit become operative. In that case, data collection stops until clear inhibit command is received. The buffers will then be updated and data collection will continue.

While the implementation of this approach will require two new board types, changes to the analog scanner chassis and backplane wiring are not required.

Connections to the EPUT boards will be made at the terminal blocks provided for connection to normal analog monitor points. Thirty pinouts are available for each board using this technique. In addition, the time base board will interface with the backplane to receive commands through the normal relay addressing technique. Also both board types will use a +5 vdc power available on the backplane.

A preliminary circuit design has been generated which can be used as a starting point in development of the EPUT. In this design, the time base is strappable in 0.5 minute increments from 0.5 to 7.5 minutes. The event counter has a full scale output of 2^{15} (32768), with the dc output voltage versus count having the following discrete values:

Event Count	Dc Output Voltage
0	0
1	0.5
2-3	1.0
4-7	1.5
8-15	2.0
16-31	2.5
32-63	3.0
64-127	3.5
128-255	4.0
256-511	4.5
512-1023	5.0
1024-2047	5.5
2048-4095	6.0
4096-8191	6.5
8192-16383	7.0
16384-32767	7.5
32768 & above	8.0

The address for the various commands are shown below. The address shown in the bit pattern that appears at the BCD address part of all ten relay boards in the analog scanner. Another signal indicates which board is to respond. When the clock board is addressed, it will respond to the BCD relay address as shown:

BCD Relay Address	Command
0001	INHIBIT LOAD
0010	CLEAR INHIBIT
0100	SELF TEST

Preliminary schematics of the circuit design are included here for reference. See Figures 3-15 through 3-19.

3.2.2 Digital Baseband Monitor: (Eye Pattern)

The purpose of the Baseband Monitor is discussed in Paragraph 3.1.2, Candidate Hardware Adaptations.

The basic requirement of the Digital Baseband Monitor is to measure the quality of the radio baseband signal between the radio and T1-4000 multiplexer.

In particular, the adaptation has the following requirements:

1. Measure amplitude of signal perturbations relative to signal level in the received radio baseband after partial response filtering.

2. Test for bursts in signal perturbations and collect burst count by use of hit counter. This data will be used to monitor short duration radio link distrubances.

3. Provide scanning capability so that several basebands can be monitored, one at a time, using the same electronics.

4. Provide automatic gain control with a range of +6 dB minimum for a nominal input amplitude of -2 dBm at 75 ohms.

5. Monitored signal will be -17 dBm at 75 ohms available at a test point at each radio receiver.

6. Provide a measure of baseband signal amplitude.

The function of the Digital Baseband Monitor in a time division multiplexed communications network is analogous to the present Baseband Monitor in a frequency division multiplexed network. The scanning function is identical. For these reasons, it is proposed that the above requirements be met by adaptation of the present Baseband Monitor.

A block diagram of the adaptation is presented in Figure 3-20.

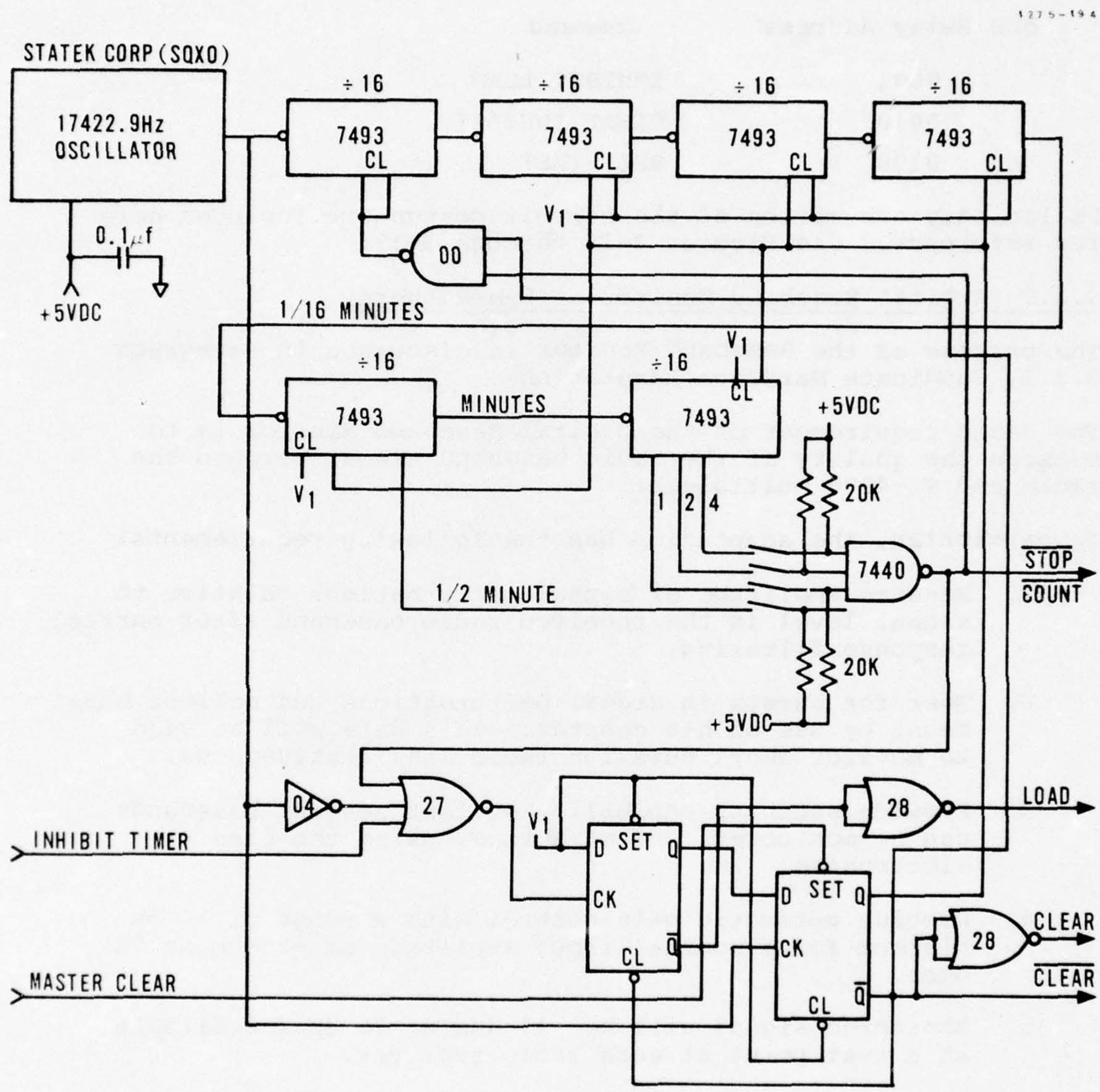

FIGURE 3-15. TIME BASE

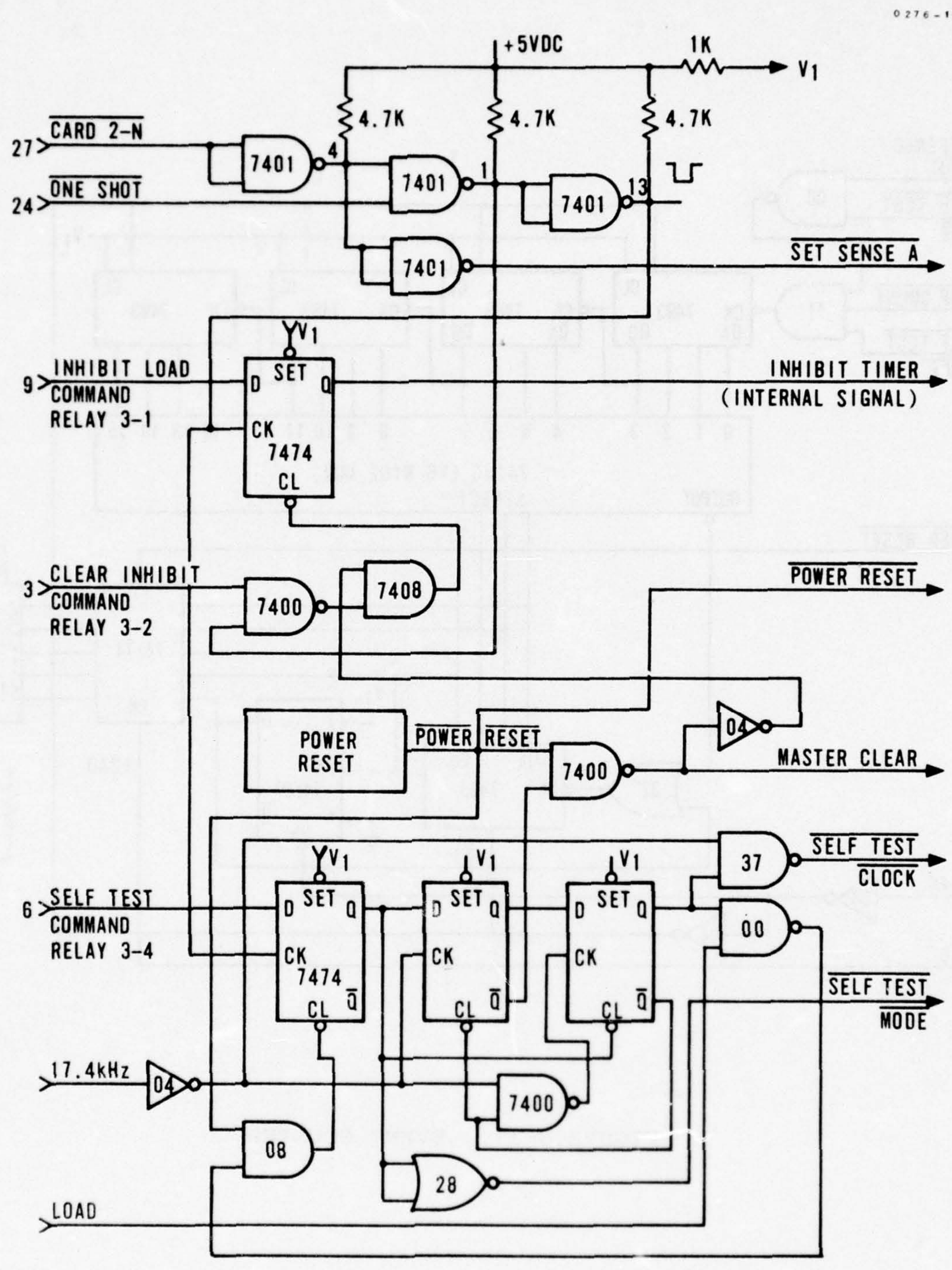

FIGURE 3-16. EPUT COMMAND CONTROL

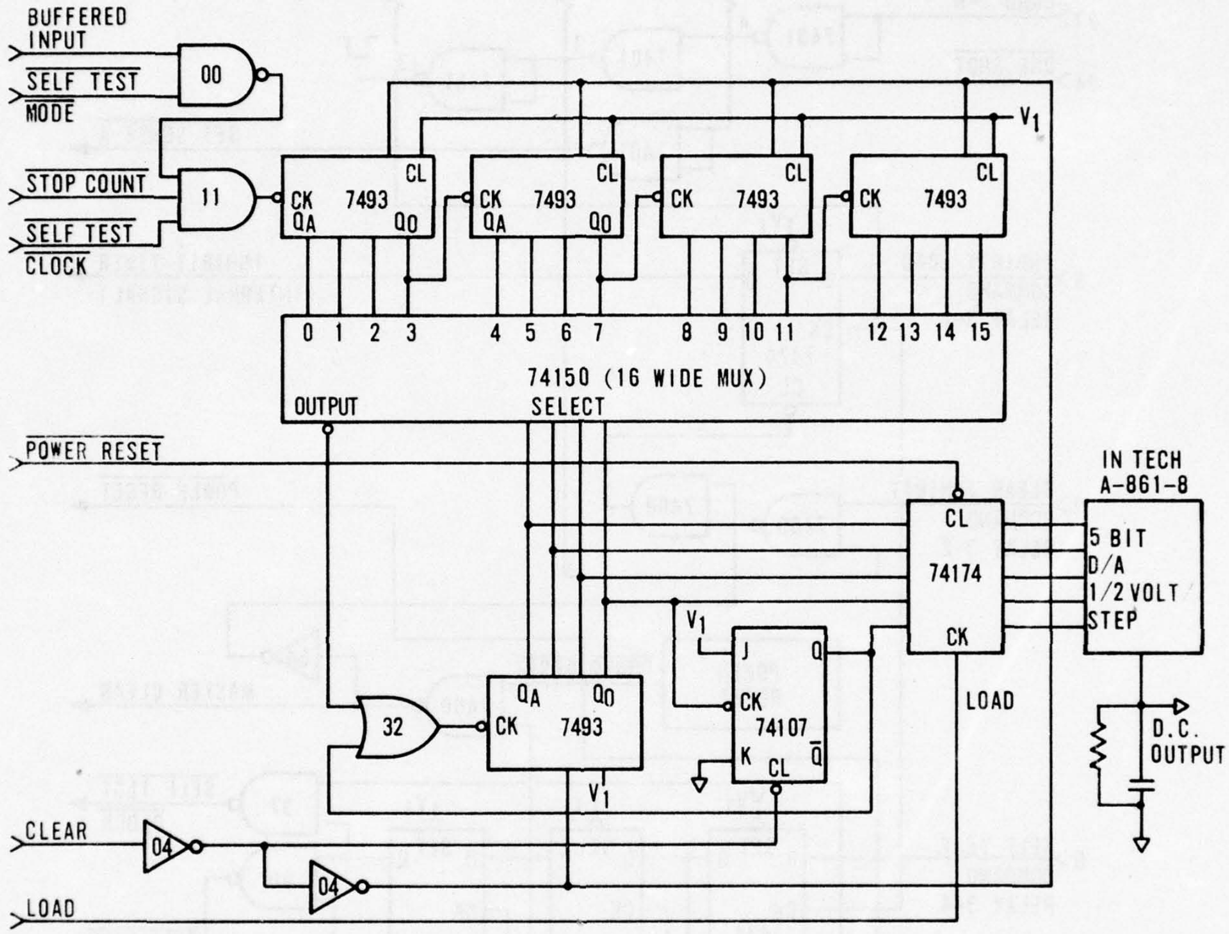

FIGURE 3-17. EVENT COUNTER

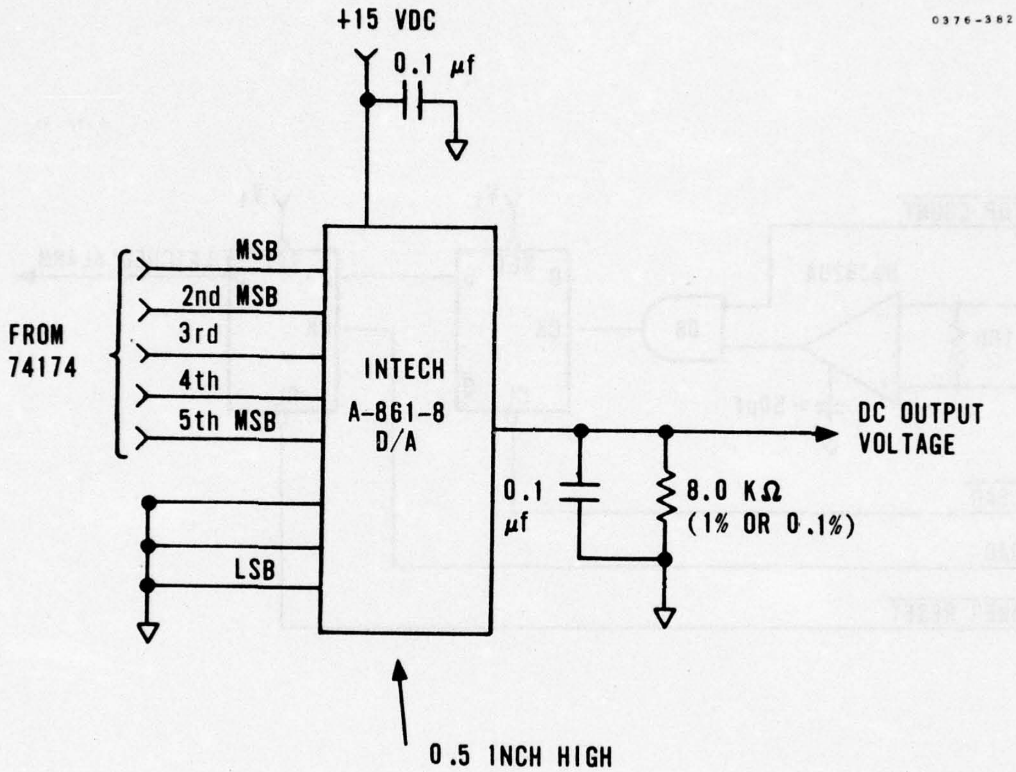

FIGURE 3-18. DIGITAL TO ANALOG CONVERTER

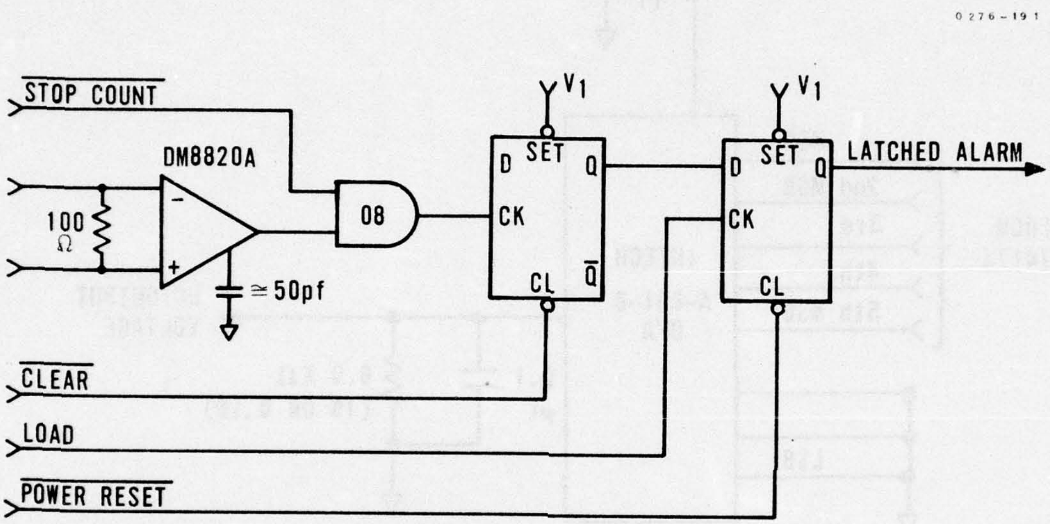

FIGURE 3-19. BUFFER INPUT AND LATCH

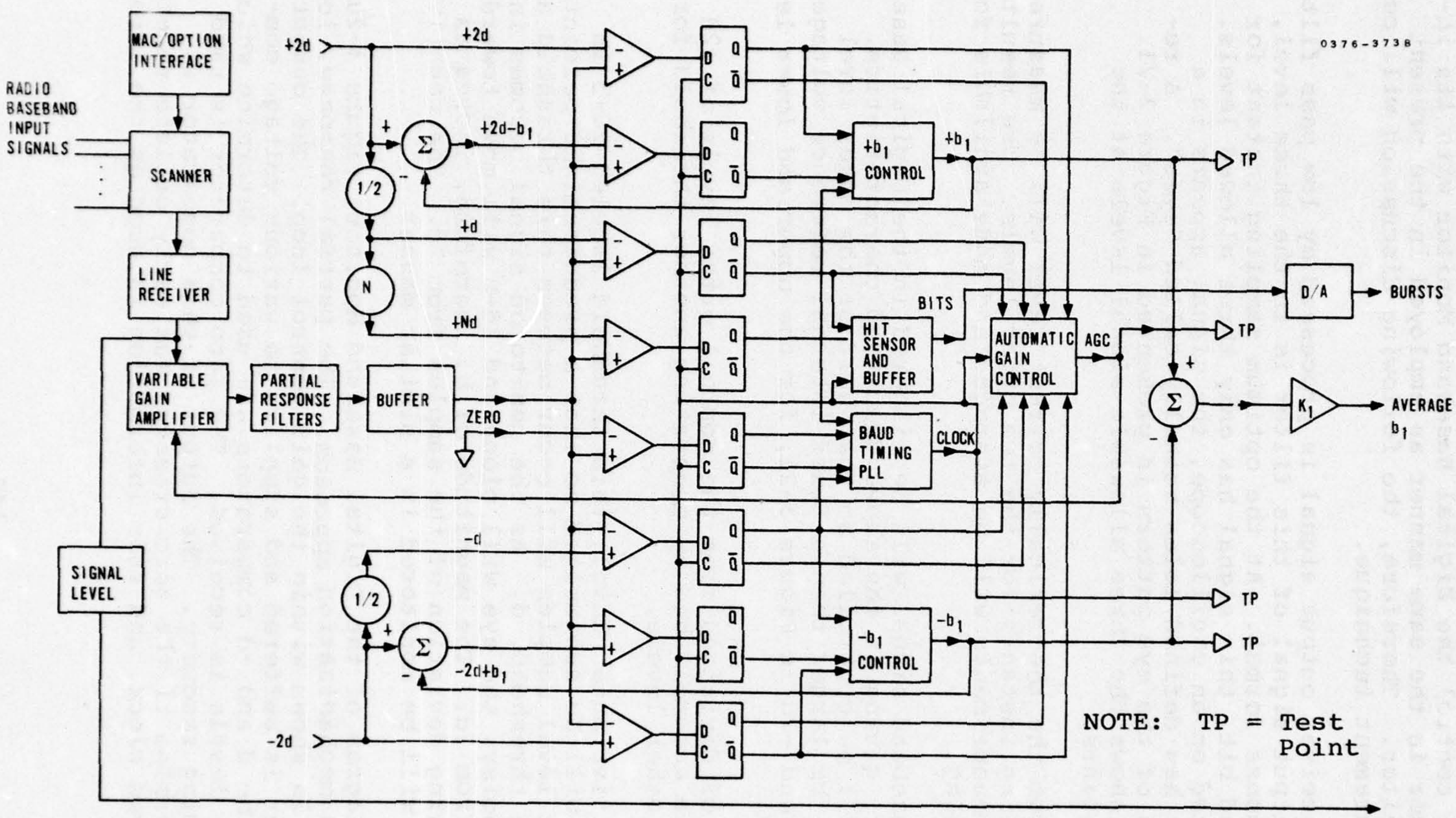

FIGURE 3-20. DIGITAL BASEBAND MONITOR (EYE PATTERN)

The MAC will control the Digital Baseband Monitor with its internal scanner in the same manner as employed in the present Baseband Monitor. Therefore, the following discussion will center on the measurement technique.

The radio receiver output signal is processed by low pass filtering. The output signal of this filter is in the three level, partial response format. At the optimum sampling instant for each received bit, this signal has only three allowed levels. When presented on an oscilloscope, the signal appears in a pattern that has defined holes normally called "eyes". A representation of the eye pattern is presented in Figure 3-21. This figure shows the three allowable signal levels at the sampling instants.

Deviation from the theoretically correct level will be measured at the sampling instants for the two outer levels. The results of the two measurements will be averaged and made available for ATEC monitoring.

The radio baseband signal will be filtered in the Digital Baseband Monitor, giving it the above described characteristics. Its amplitude will be controlled so that half of the outer level samples will be larger than a fixed internal reference voltages, labelled 2d and -2d in Figure 3-21, for the upper and lower levels respectively.

Measurement of deviation from the nominal outer levels of ±2d volts will be accomplished by generating another threshold for each of the other levels.

For the positive outer level, this threshold labeled 2d-b in Figure 3-21 will be controlled so that a predetermined percentage of the outer level samples will occur between this threshold and the decision threshold, d. As the monitored signal becomes increasingly noisy, the eye will close and 2d-b will move toward d and away from 2d. The magnitude of b, therefore, increases with increasing deviation of the samples from 2d. The negative outer level will be monitored in a similar manner.

The block diagram of the Digital Baseband Monitor, Figure 3-20, presents the mechanization approach. The partial response, low pass filter is shown within the gain control loop. The output of the filter is buffered and supplied to various voltage comparators. The d and -d comparators are used to determine which of the three levels is received. The zero comparator is used for baud timing recovery. The output of this comparator is used to determine if the zero crossing was early or late relative to the derived clock, and this information is used as the error

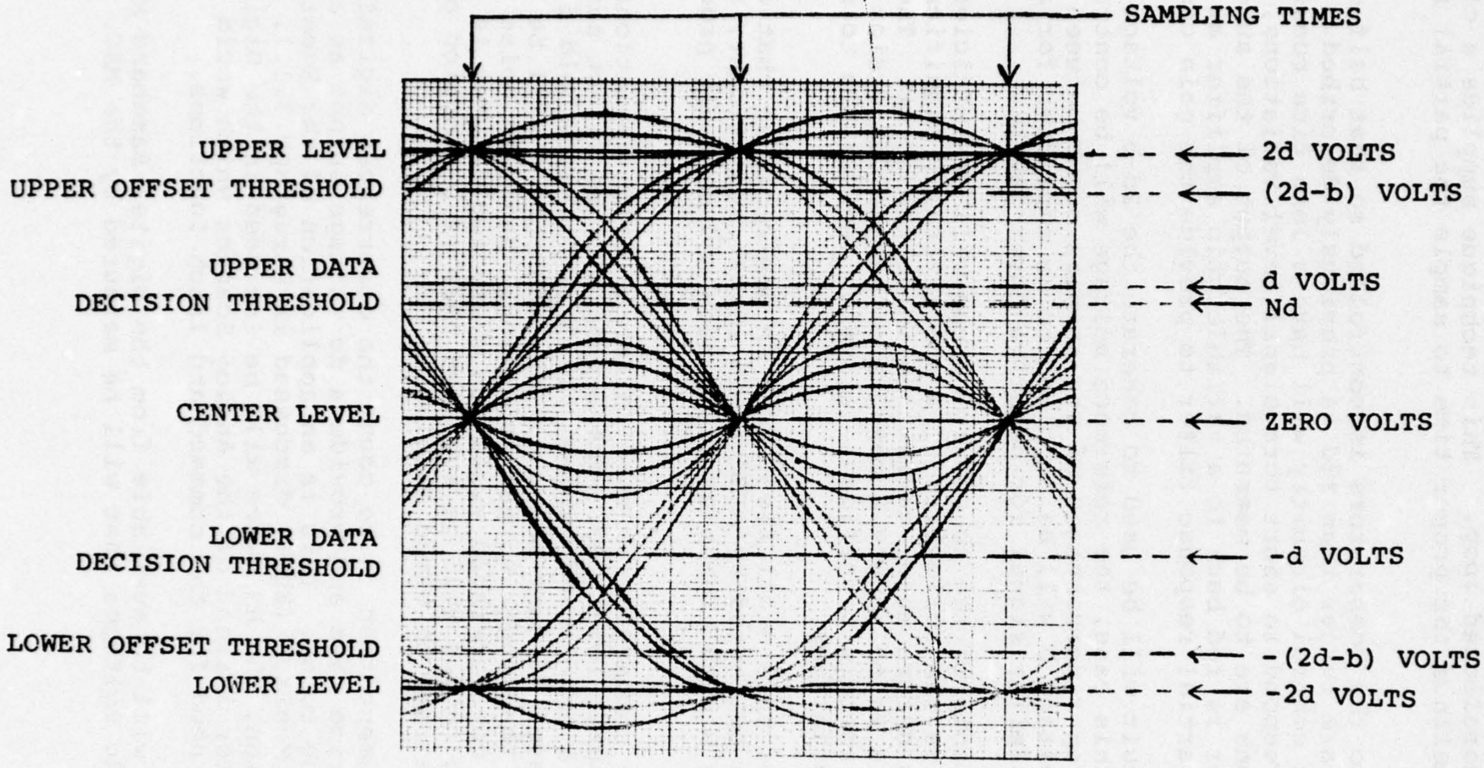

FIGURE 3-21. DEFINITION OF LEVELS FOR OFFSET THRESHOLD MONITORING OF THREE LEVEL EYE

signal in a phaselocked loop. This technique supplies a clock signal which defines the proper time to sample the partial response signal.

Signal level to the comparators is controlled so that half of the outer samples are larger than ±2d as previously described. The automatic gain control circuitry will have a long time constant so as not to respond to short term signal level variations, since these variations are to be measured. The output of the automatic gain controller is fed back to a variable gain amplifier at the input to the partial response filter to provide the gain control.

A similar circuit will be used to generate the 2d-b voltage reference. In this case, the reference voltage will be controlled so that the proper percentages of the samples occur between 2d-b and d. The voltage b will be supplied to an amplifier for averaging with a similar signal for negative outer levels.

The time constants of the ±b control loops will be sufficiently large to require the collection of a statistically significant number of bits before major variations in ±b can occur. The purpose of this is to supply a measure of sample dispersion that does not contain significant variation (noise) due to normal statistical variations.

Presentation of this statistical mean is desirable so that each sample of data collected by ATEC is in itself significant, rather than requiring a much higher sampling rate and software processing.

Another single comparator is used to detect major deviations from the positive outer level, 2d. The approach is to detect samples that occur in a narrowband between the decision threshold d and a reference level Nd just below d. The value of N will be selected such that under normal conditions, Gaussian noise in the baseband, one threshold violation every few minutes is collected. An output will be supplied that is a function of the occurrence rate of these samples.

A likely implementation is to count the occurrences digitally over a fixed time base and provide a dc voltage output as a function of the count. This is an application of the Events Per Unit Time Monitor (EPUT) discussed in Paragraph 3.1.1. In this application, the hardware will be included in the Digital Baseband Monitor instead of the Analog Scanner which would eliminate the need for the command and latch functions.

Three outputs will be available from the Digital Baseband Monitor; all are dc voltages that will be measured by the MAC. These

are: average eye dispersion, bursts (EPUT), and radio baseband signal level. Signal level will be measured to detect degradation in amplitude that may not also appear as eye dispersion. At time of installation, an eye dispersion versus RSL calibration table is generated. The value of RSL corresponding to the measured eye dispersion is compared to the RSL value corresponding to the PCM threshold (-71 dBm). The difference is the Baseband Eye Margin. The measured value of eye dispersion and the baseband eye amplitude can be combined to provide the actual S/N ratio of the baseband eye. Knowing the signal to noise ratio and assuming that additive noise is basically Gaussian, the calculated BER can be determined. This is more fully discussed in Appendix A.

A block diagram of the existing Baseband Monitor hardware, showing a possible arrangement of substitute boards for implementation of the Digital Baseband Monitor is presented in Figure 3-22. Schematics of preliminary circuit design for the major new functions of the Digital Baseband Monitor are presented in Figures 3-23 through 3-26 for reference. These circuits will serve as a starting point for development of the electronics.

A detailed discussion of the merits of eye pattern monitoring and a mathematical analysis of a conceptual approach is presented as Appendix A of this volume. The recommended implementation for eye pattern monitoring differs from the approach outlined in Appendix A in two areas. First, the analysis does not address the existence of intersymbol interference which, as a result of additional study, is believed to be the largest single contributor to residual eye pattern noise. Under normal conditions with the equipment operational, the density distribution function of intersymbol interference will be normal (Gaussian). In the event of an analog circuit failure in the T1-4000, the distribution will not be normal, but will be an indeterminate expression caused by intermodulation distortion and harmonic distortion products. Second, a means must be provided for compensating for the residual eye noise (intersymbol interference) under high received signal to noise ratios in order to accurately measure degradation due to increased noise introduced in the receiver front end.

Total noise affecting eye pattern is the sum of the intersymbol interference and radio noise. Under normal operating conditions intersymbol interference is normally distributed. Radio noise is also normally distributed since it results from thermal sources. The sum of two variables which are of normal distribution is also normal in distribution. Therefore, it has been

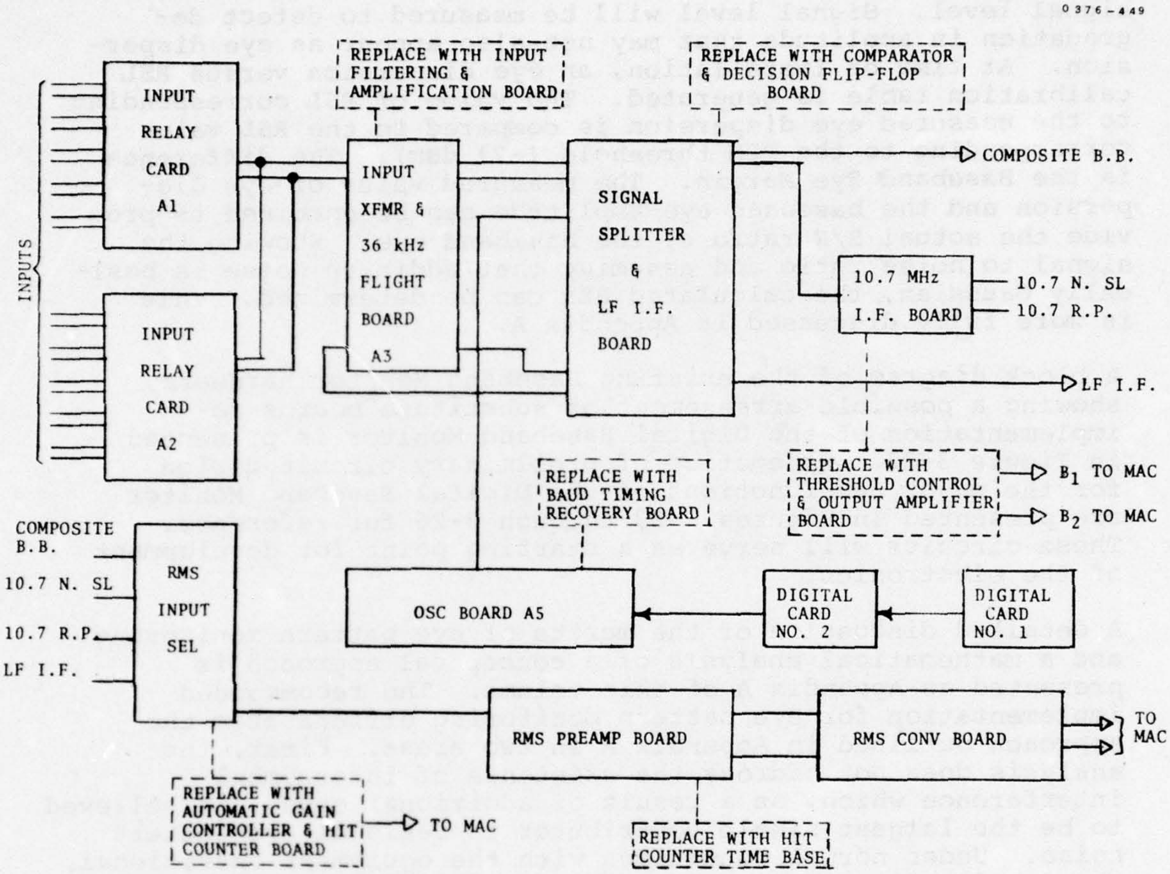

FIGURE 3-22. BLOCK DIAGRAM BASEBAND PARAMETER CONVERTER

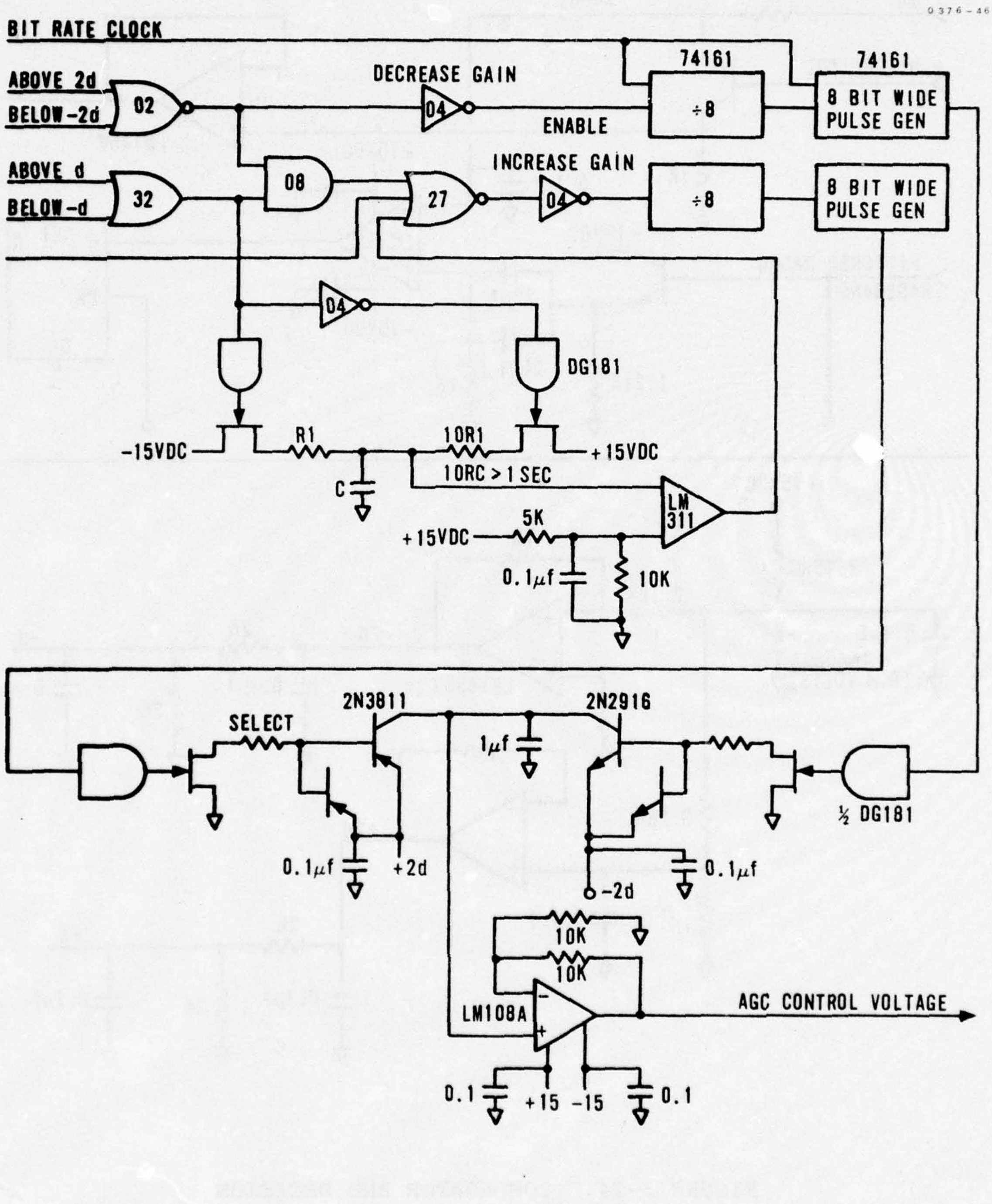

FIGURE 3-23. AGC CIRCUIT

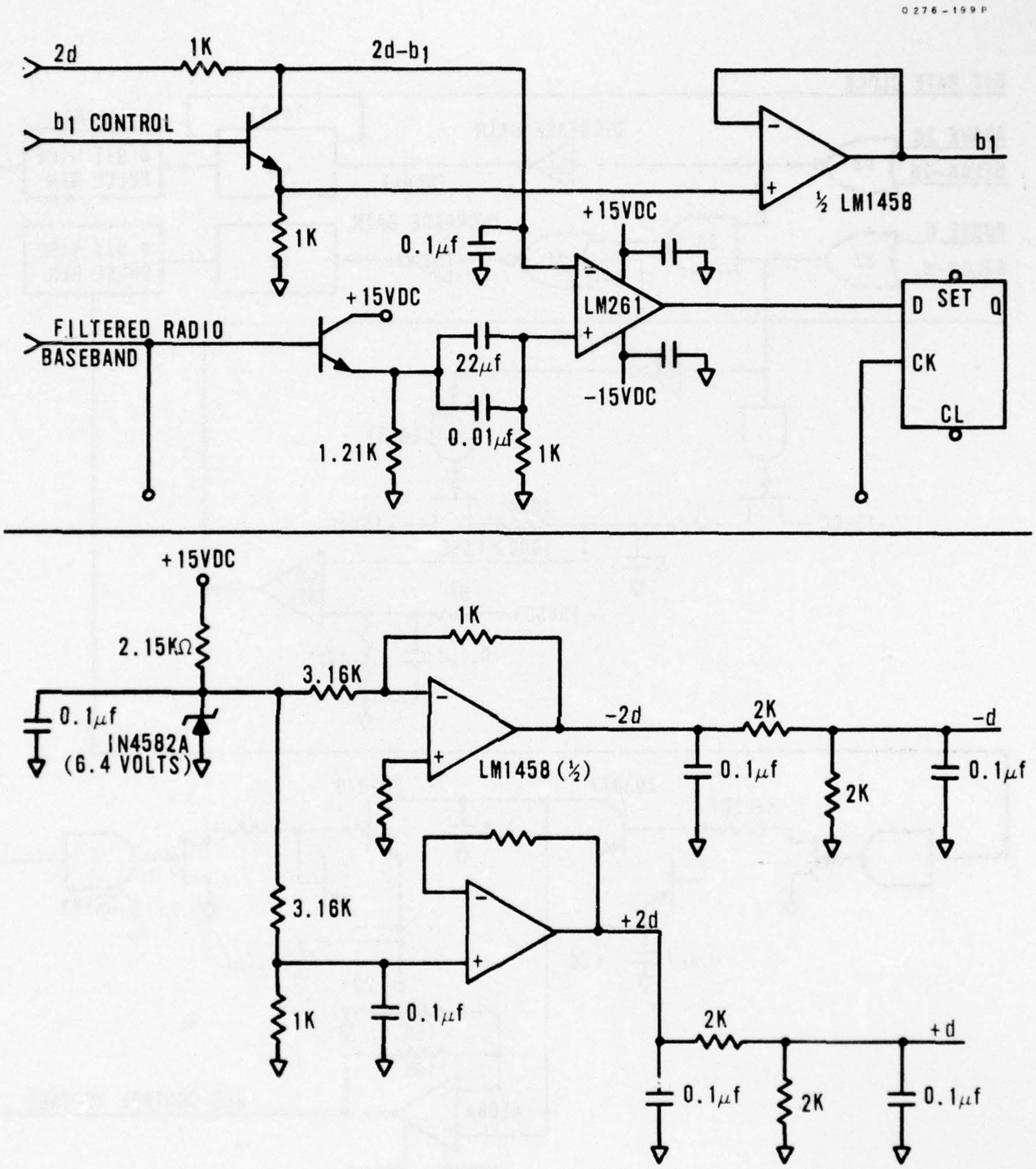

FIGURE 3-24. COMPARATOR AND DECISION
FLIP FLOP BOARD (DBM)

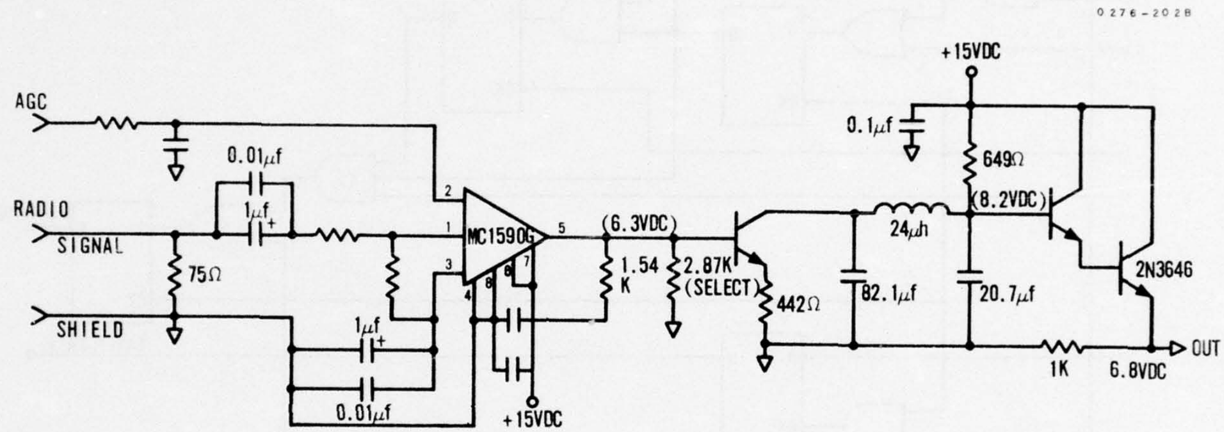

FIGURE 3-25. INPUT FILTERING AND AMPLIFICATION BOARD (DBM)

0276-1978

UPDATE CONTROL

DATA	F-FA	F-FB
1	1	0
$0 \cdot A$	1	1
$0 \cdot \bar{A}$	0	0
-1	0	0

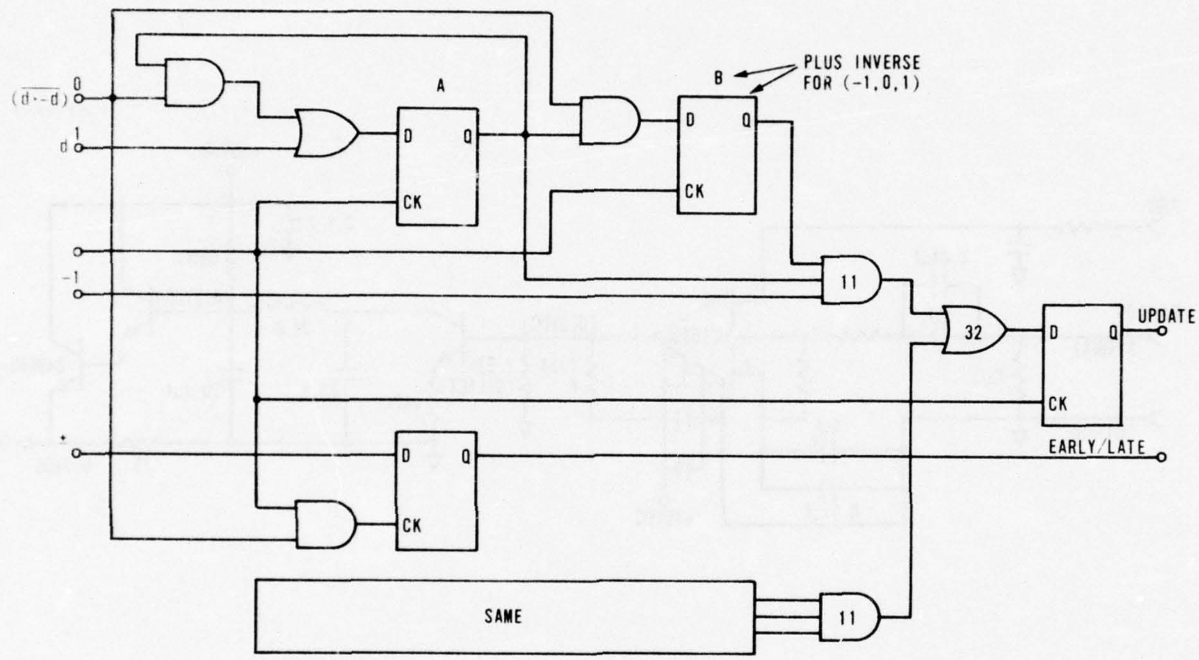

FIGURE 3-26. CLOCK RECOVERY PHASE COMPARATOR

concluded that noise affecting the eye pattern can be assumed to have A Gaussian distribution under normal operating conditions, thereby eliminating the need for measurement of an additional pseudo error rate threshold for confirmation of a Gaussian distribution.

3.2.3 Voice Data Combiner Telemetry Error Control

The purpose of the error detector is presented in Paragraph 3.1.3. This adaptation is not recommended for inclusion in the FKV demonstration because it is not essential to the validation of the FKV monitor concept.

The basic functional requirement of the error detection unit is to detect errors in long haul transmission of Alarm Scanner data and to react appropriately to minimize the probability of incorrect interpretation of alarm states.

The detailed requirements are as follows:

1. Generate an error detecting code for each stop/start character in the Alarm Scanner data format and transmit the code following the character.

   The transmission format for Alarm Scanner data is ten bit start/stop characters with each character separated by fifteen (15) bit periods. These characters are transmitted in a format that starts with a "begin" character. A given alarm has a dedicated position in this format for transmission of its state. It will always be transmitted in the same character relative to the start character and the same bit position within that character. When all alarms from an Alarm Scanner have been transmitted, the start character will again be transmitted and the format will repeat itself.

2. Use the 75 bits per second transmission rate.

3. When a character containing no errors is received, pass it on and also store it.

4. When an error is detected in a character, discard the character and pass on the most recently stored character from memory for that location in the format.

The selected approach is to use a (31, 21) BCH code modified for use on ten bits. The code itself will consist of ten transmitted bits thus giving a total of twenty bits, transmitted for each stop/start character. This code is capable of detecting any four or less random errors in the start/stop character and BCH code. Errors that occur in bursts are more easily detected than random errors. The code will detect all bursts of ten or less bits in length. The probability of not detecting an error in a character under the influence of a binominal error distribution with means of 10^{-3} is less than 1.5×10^{-11}.

A block diagram of an implementation is presented in Figure 3-27. The electronics would be housed in the Voice/Data Combiner which presently contains the modems necessary for transmitting digital data over analog communications links. Two spare board locations are available for use. The error detection coding and decoding will be done on the digital side of the transmit and receive modems respectively.

The error detection unit transmitter, as shown in Figure 3-27, requires bit timing recovery and start/stop character synchronization. This function is necessary to allow the BCH code generator to calculate code on the appropriate bits and to transmit those bits at the proper time.

Bit timing recovery and character synchronization may be implemented using a digital phase locked loop using a frequency source of (64) x (75) Hz. For practical implementation, a timing fork oscillator at a higher frequency may be used with the required frequencies generated with digital count down chains.

The BCH generator is a ten bit shift register with six of the flip flops having an input originating from a simple Exclusive OR of the transmitted bits and the previous flip flop output.

The selector is used for insertion of the calculated BCH code following the start/stop character. During transmission of the BCH code, the BCH generator acts as a simple shift register, by inhibiting the Exclusive OR function.

The receiver portion of the error detection unit performs all of the functions of the transmitter. It will recover bit timing and synchronize to the start/stop format which of course has been modified by the addition of BCH code. A BCH generator will generate code on the ten bits of the start/stop character in exactly the same manner as was done in the transmitter, but here the similarity stops.

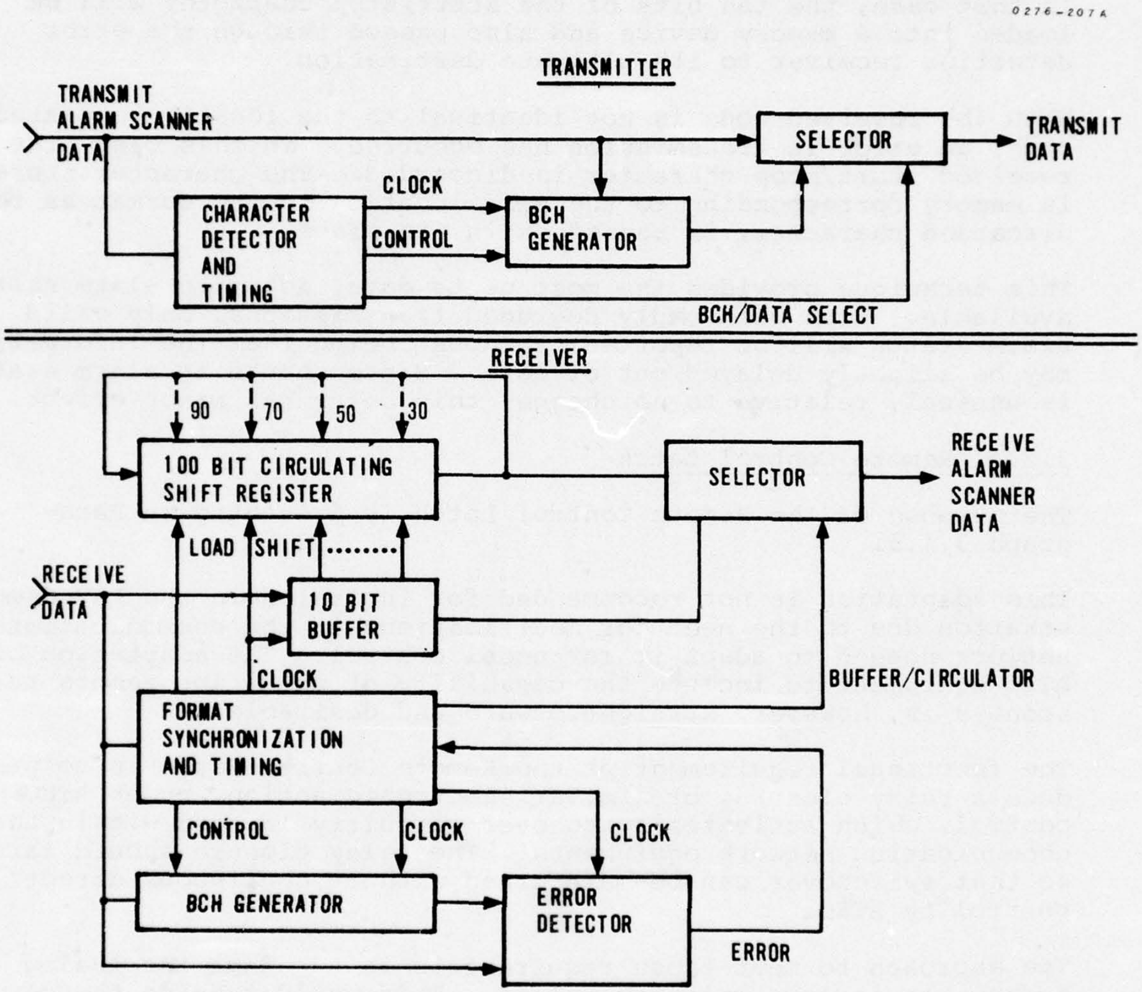

FIGURE 3-27. ERROR DETECTION UNIT

As the start/stop character is being received, it will be stored in a ten bit shift register and remain there until receipt of the BCH code is complete. As the code is being received, it will be compared bit by bit to the code generated in the receiver. If transmission was error free, the two codes will be identical. In that case, the ten bits of the start/stop character will be loaded into a memory device and also passed through the error detection receiver to its ultimate destination.

When the received code is not identical to the locally generated code, an error in transmission has occurred. In this case, the received start/stop character is discarded. The character stored in memory corresponding to the same location in the format as the discarded character, is passed on in its place.

This technique provides the most up to date, accurate alarm status available. Even with badly degraded transmissions, only valid alarm status will be reported; the cost being that the information may be slightly delayed/out of date. Since change in alarm status is unusual, relative to no change, this delay has minor effect.

3.2.4 Remote Control Latch

The purpose of the Remote Control Latch is presented in Paragraph 3.1.5.

This adaptation is not recommended for inclusion in the FKV demonstration due to the need for modifications in the communications network needed to adapt it for nodal control. The adaptation of ATEC equipment to include the capability of actuating remote responses is, however, straightforward and desirable.

The functional requirement of the Remote Control Latch is to produce a relay closure, or similar electronic action, under ATEC control, which activates switchover circuitry located within the communication network equipments. The relay closure should latch so that switchover can be maintained without continuous direct control by ATEC.

The approach to meet these requirements is to adapt the Analog Scanner to include latching relays. This would require the development of a new circuit board type, but requires no change to the chassis or internal wiring.

Five control relays per board are possible, using the existing terminal block for connection to the controlled electronics. Latching and clearing of each relay can be addressed using the normal form A relay card addressing technique, which provides

ten addresses per board. Five of these addresses can be used as commands to latch the five control relays; the other five commands for clear.

In addition, it may be desirable to provide one contract from each relay to be monitored by other relays in the Analog Scanner. This would provide a means of determining the state of each latch.

The use of latching relays is significant from a fail safe viewpoint. With loss of communications to the Analog Scanner or loss of power at the scanner, the relays will maintain their state and thus the communications network will remain in the desired configuration. In addition, remote control in the FKV would be used to override the local automatic protection switching. Assuming that overriding the local switch function is the unusual situation, a failed Analog Scanner will normally still allow local automatic switching. Remote control switching should always be implemented to allow local manual control independent of ATEC remote control or local automatic switching. The recommended hierarchy of control is first local manual, then ATEC remote, and last local automatic control.

Application of the Remote Control Latch in the FKV is presented in the following block diagrams.

An approach for remote control of the T1-4000 transmitter protection switch is presented in Figure 3-28. Provision to force the normal transmitter on line is provided by the local protection switch. Switching to standby transmitter requires modification to the local protection switch.

An approach for remote control of the T1-4000 receiver protection switch is presented in Figure 3-29. A modification to the local protection switch is required for transfer of the standby receiver on line.

Local manual control has priority in the approach presented for T1-4000 control.

An approach for remote control of the radio receiver switch is presented in Figure 3-30 and for the radio transmitter switch in Figure 3-31. The approach presented directly controls the signal that actuates the switch; therefore, local manual control does not have priority. Implementation of manual control would require further modification, such as switches with the same configuration as the relays shown, but located between the relays and the switch.

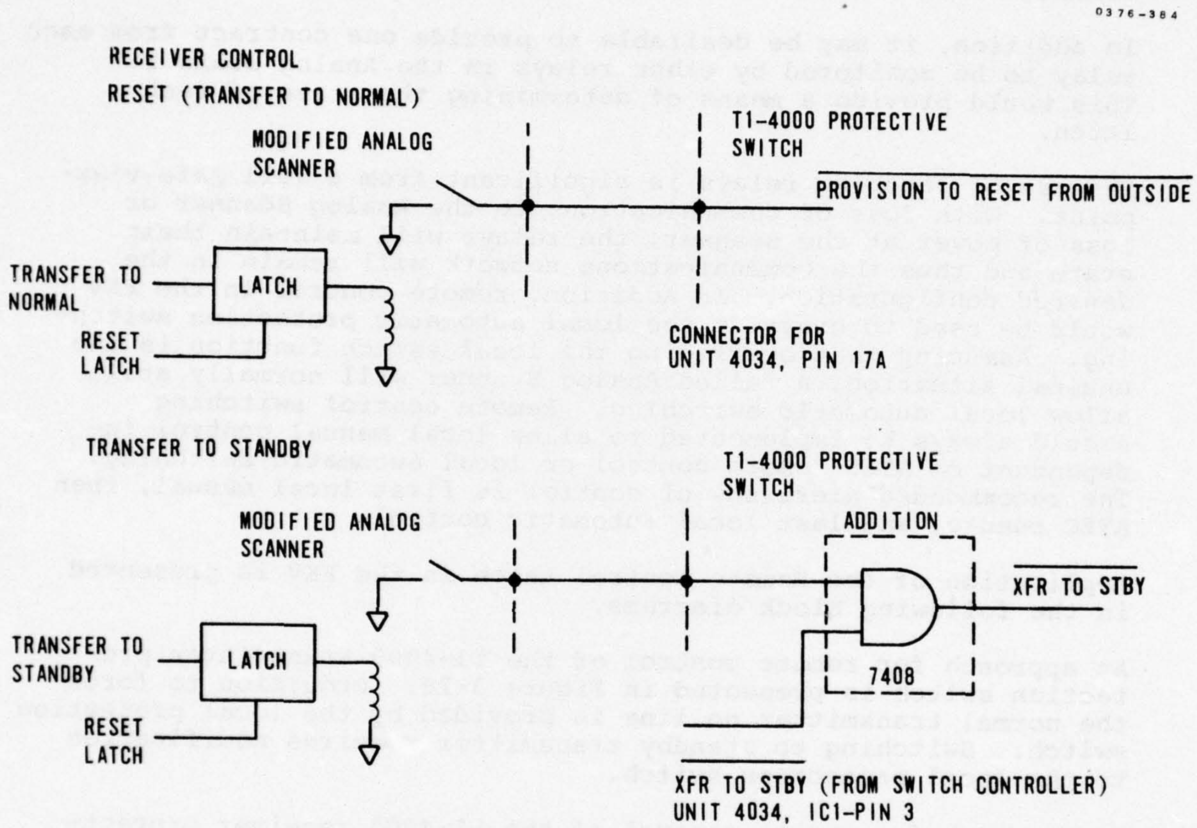

FIGURE 3-28. CONTROL OF T1-4000 PROTECTIVE SWITCH

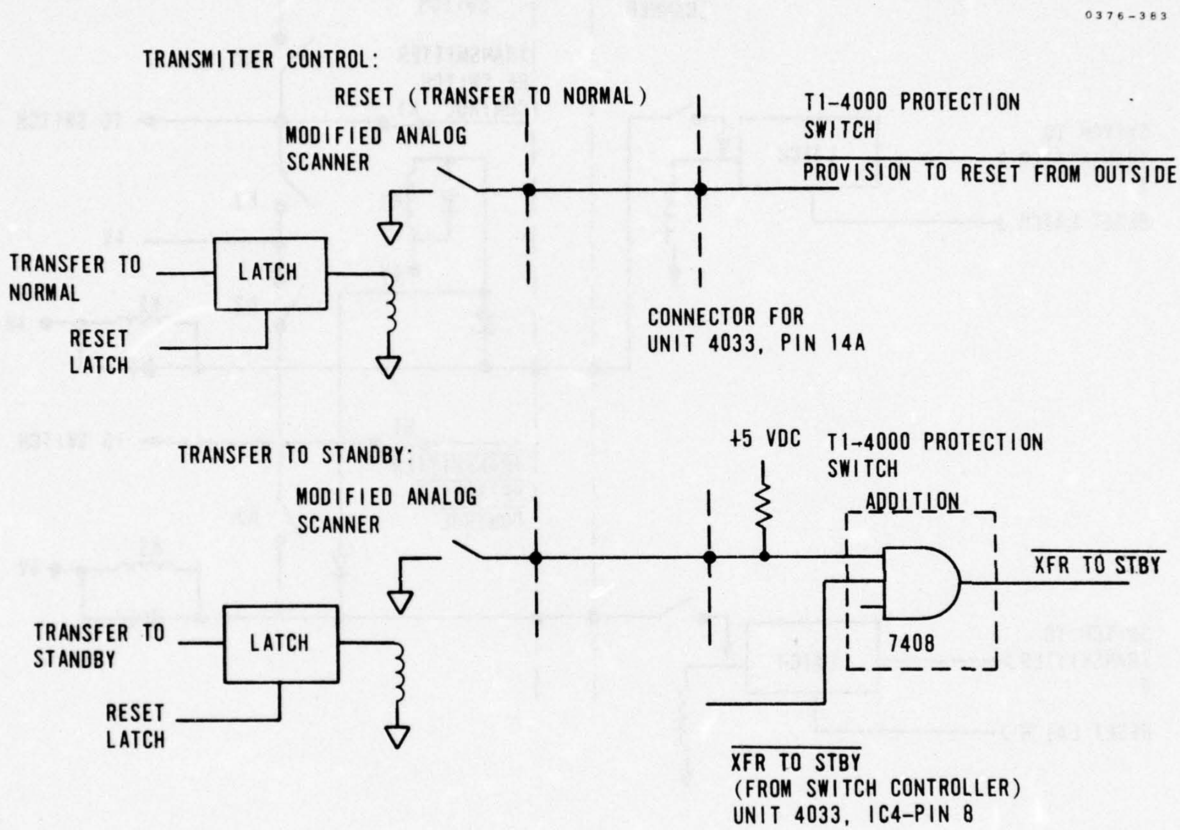

FIGURE 3-29. CONTROL OF T1-4000 PROTECTIVE SWITCH

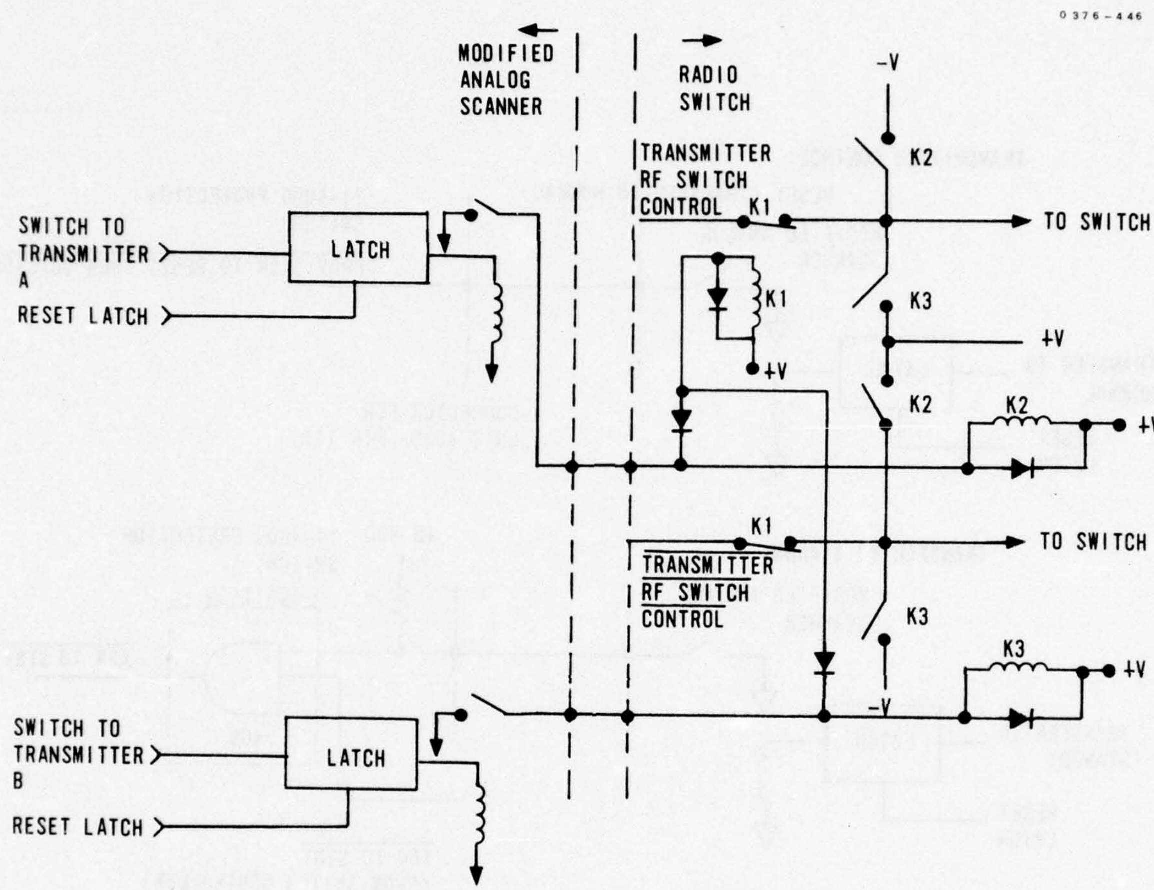

FIGURE 3-30. CONTROL OF RADIO TRANSMITTER SWITCH

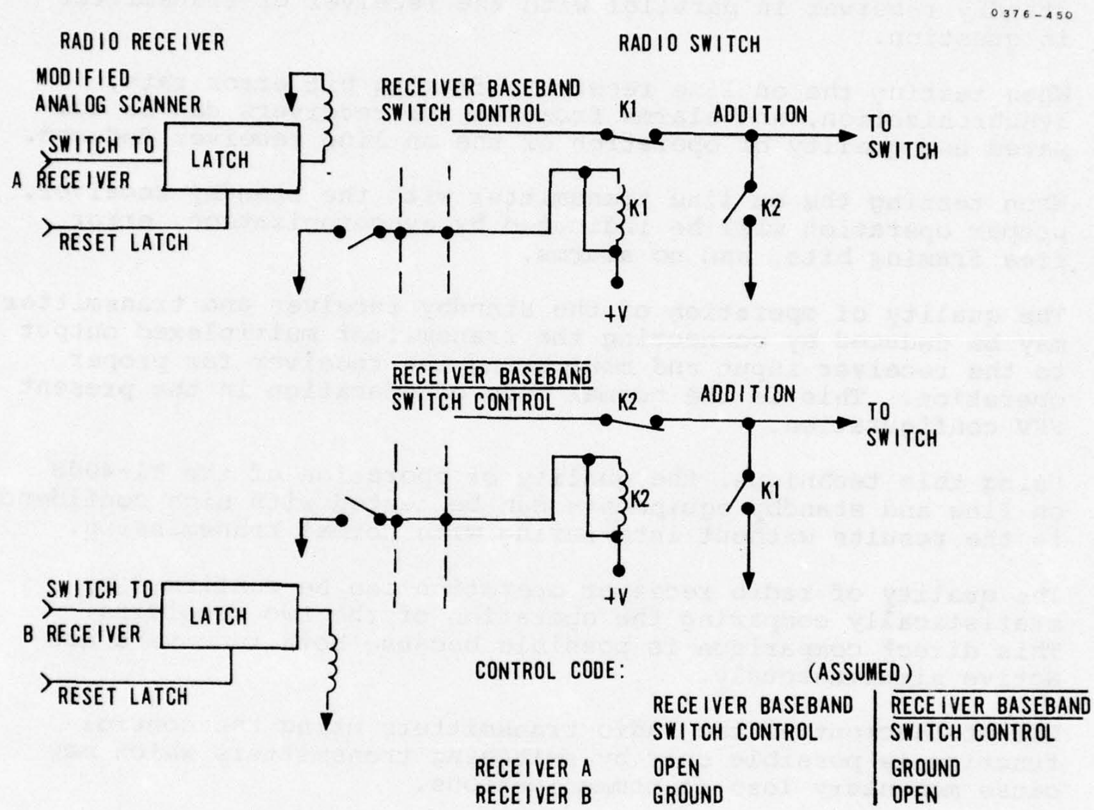

FIGURE 3-31. CONTROL OF RADIO RECEIVER SWITCH

An approach to remote control that increases the ability to fault isolate is presented in Figure 3-32. This approach provides the capability to use the standby T1-4000 multiplexer receiver as test equipment to verify operation of the on line receiver or transmitter. This is implemented by switching the standby receiver in parallel with the receiver or transmitter in question.

When testing the on line receiver, framing bit error rate, synchronization, and alarms from the two receivers can be compared and quality of operation of the on line receiver deduced.

When testing the on line transmitter with the standby receiver, proper operation will be indicated by synchronization, error free framing bits, and no alarms.

The quality of operation of the standby receiver and transmitter may be deduced by connecting the transmitter multiplexed output to the receiver input and monitoring the receiver for proper operation. This is the normal mode of operation in the present FKV configuration.

Using this technique, the quality of operation of the T1-4000 on line and standby equipments can be tested with high confidence in the results without interfering with normal transmission.

The quality of radio receiver operation can be confirmed by statistically comparing the operation of the two receivers. This direct comparison is possible because both receivers are active simultaneously.

Direct checkout of the radio transmitters using the control function is possible only by switching transmitters which may cause momentary loss of communications.

The technique of fault isolation using hardware substitution is the most effective and simple approach available. With redundant equipment and remote control switching available, this is a practical, cost effective approach.

3.3 RECOMMENDED SOFTWARE

3.3.1 Introduction

The recommended approach to nodal control monitoring of the FKV network consists of sudden service failure sensing using alarm scanners, alarm display units, and a MAD augmented by a software

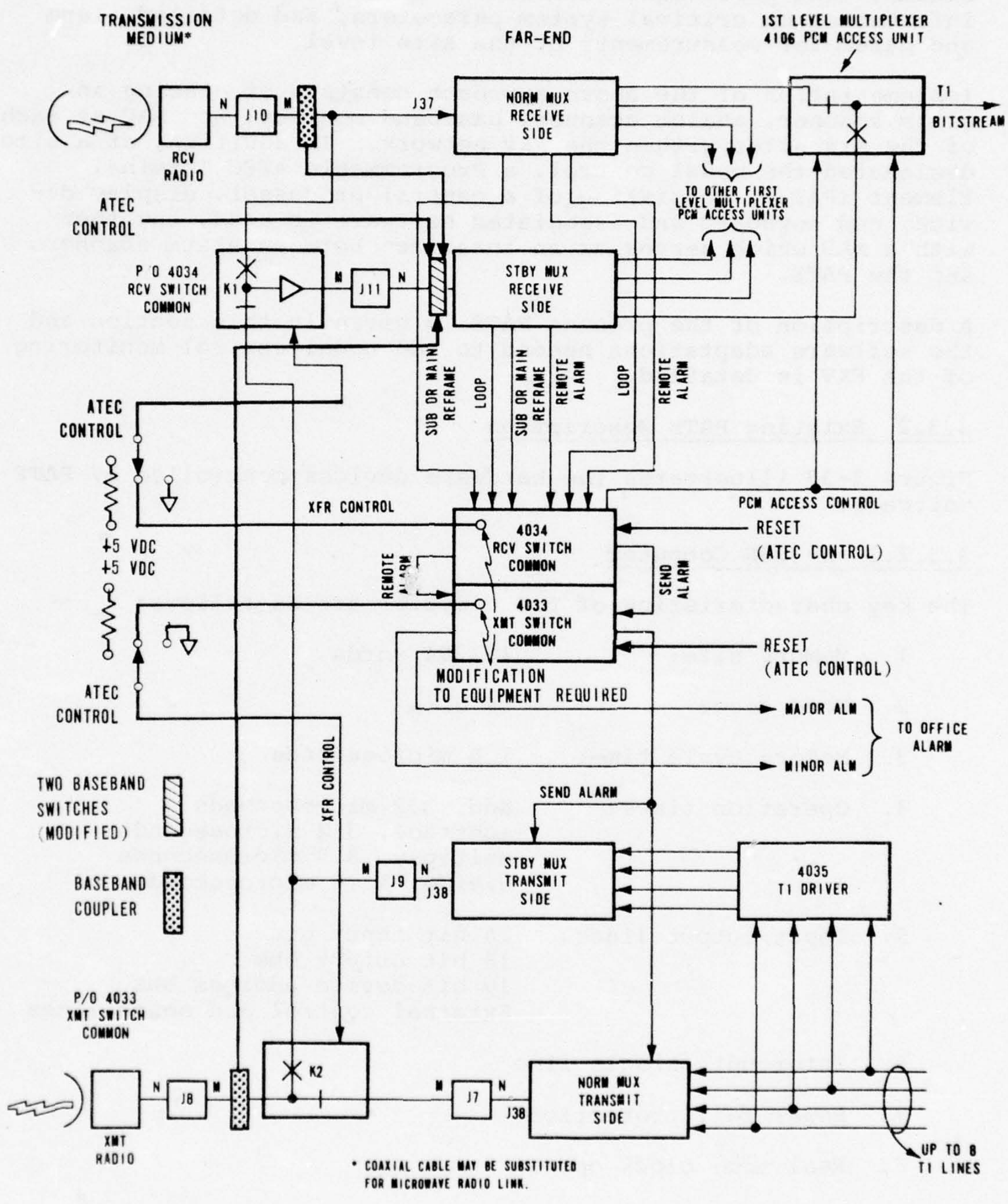

FIGURE 3-32. FIRST LEVEL MUX PROTECTION SWITCH SYSTEM BLOCK LEVEL SIGNAL FLOW (NORMAL 1 CONDITION)

package which provides a system status overview, requested link status, link performance assessment in the form of statistical information on critical system parameters, and detailed alarm and parameter measurements at the site level.

Implementation of the above approach consists of placing an alarm scanner, analog scanner, baseband monitor, and MAC at each of the six sites within the FKV network. In addition, at a site designated the nodal control, a Programmable ATEC Terminal Element (PATE), consisting of a central processor, display device, and keyboard and associated software is used, together with a MAD which serves as an interface between alarm scanners and the PATE.

A description of the present PATE is given in this section and the software adaptations needed to add nodal control monitoring of the FKV is detailed.

3.3.2 Existing PATE Description

Figure 3-33 illustrates the hardware devices controlled by PATE software.

3.3.2.1 H-316R Computer

The key characteristics of the computer are as follows:

1.	Memory size:	16,384 words
2.	Word size:	16 bits
3.	Memory cycle time:	1.6 microseconds
4.	Operation times:	add, 3.2 microseconds subtract, 3.2 microseconds multiply, 8.8 microseconds divide, 17.6 microseconds
5.	Input/output lines:	16 bit input bus 16 bit output bus 10 bit device address bus External control and sense lines

6. Interrupt, single line

7. Power fail protection

8. Real time clock option

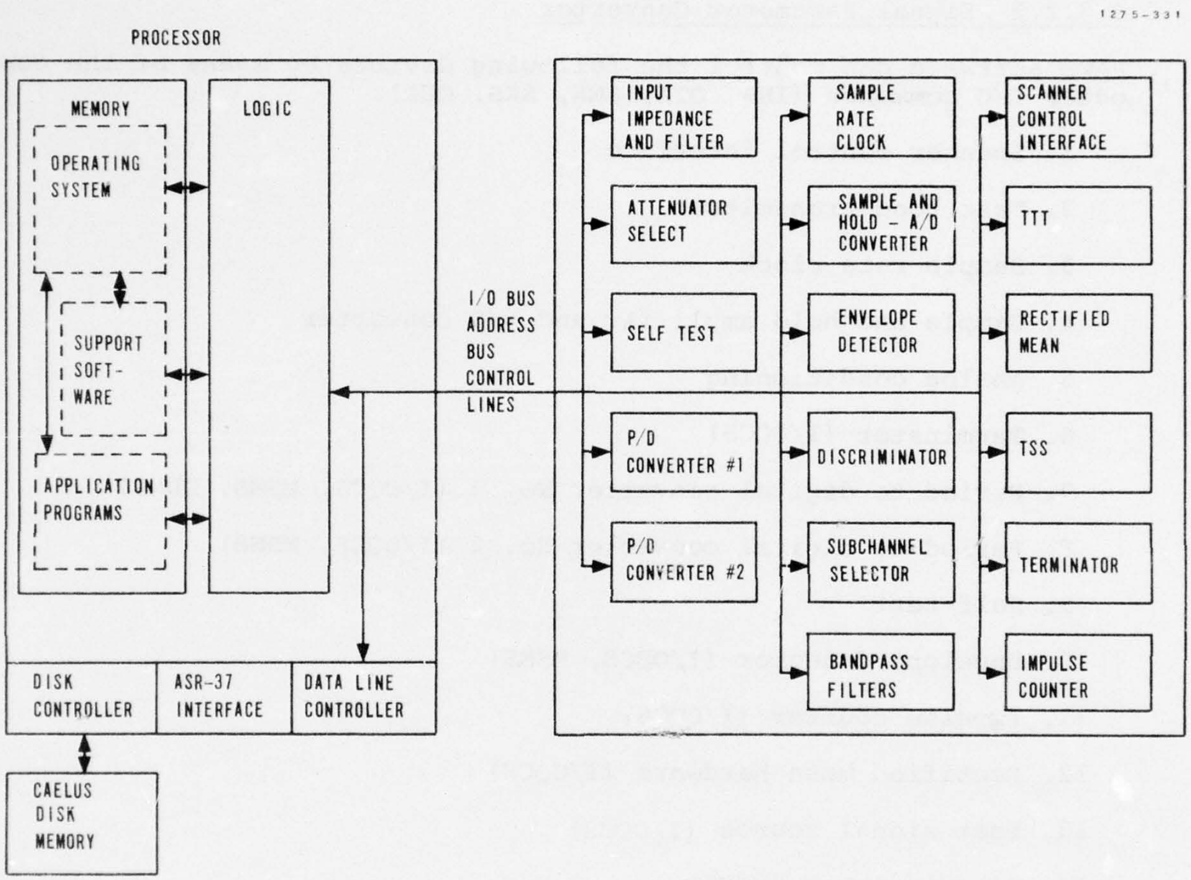

FIGURE 3-33. HARDWARE INTERFACE

9. Extended mode option

10. High speed arithmetic unit option

11. High speed DMC option - maximum transfer rate of one word every two memory cycles

3.3.2.2 Signal Parameter Converter

PATE software can control the following devices by means of the computer I/O commands (INA, OTA, SMK, SKS, OCP).

1. Scanner control interface

2. Test tone transmitter

3. Sample rate clock

4. Sample and hold amplifier and A/D converter

5. Analog conditioning

6. Terminator (I/OQCS)

7. Period to digital converter No. 1 (I/OQCS, MSMS, DDMS)

8. Period to digital converter No. 2 (I/OQCS, MSMS)

9. Self-test

10. Envelope detector (I/OQCS, MSMS)

11. Impulse counter (I/OQCS)

12. Rectified mean hardware (I/OQCS)

13. Test signal source (I/OQCS)

14. Discriminator (MSMS)

15. Subchannel selectors (MSMS)

16. Bandpass filters (MSMS)

A complete list of control commands can be found in the PATE Part I specification.

3.3.2.3 Data Line Controller

The data line controller has the following characteristics:

1. Full or half duplex operation

2. 150 baud transmission rate

3. Transmit and receive interrupt capability

4. Serial character input

3.3.2.4 Caelus Disk

The disk and controller have the following characteristics:

1. Two double surface packs, one fixed and one removable

2. 1.2 megabit capacity with redundancy, 2.4 megabit using both packs

3. Average seek time - 60 milliseconds

4. Average latency time - 12.5 milliseconds

5. Sector compare time - 2 milliseconds

3.3.2.5 PATE Software

The PATE software is highly modular and generalized to handle many differing tests in the same processor. It consists of an operating system that schedules, loads, and executes tasks on a priority or timed basis, support software for system loading, patching and debug activities and application software for performing measurement tasks such as IQCS, DDMS, etc.

3.3.2.6 Operating System

Figure 3-34 illustrates the functional flow of the operating system.

3.3.2.7 Time of Day Scheduler

This section of the operating system is responsible for scheduling tasks in either of two modes: (1) recurring, or (2) one time. It runs from a table containing task names, the time at which scheduling is to occur, and, if recurring, the interval between task scheduling.

Scheduling in the PATE operating system is two-level as shown in Figure 3-35. The scan sequencer, time of day scheduler, and application software enter information into a table called the task schedule stack (TSS) by means of a system routing called the task schedule stack administrator (TSSA). The TSSA runs with interrupts disabled and is therefore designed to do its job very rapidly. The remainder of the operating system runs with interrupts enabled. This is the main reason for the two level operation.

3.3.2.8 Task Scheduler

The tasks scheduler transfers information from the TSS to any one of four priority queues called task control blocks (TCBs).

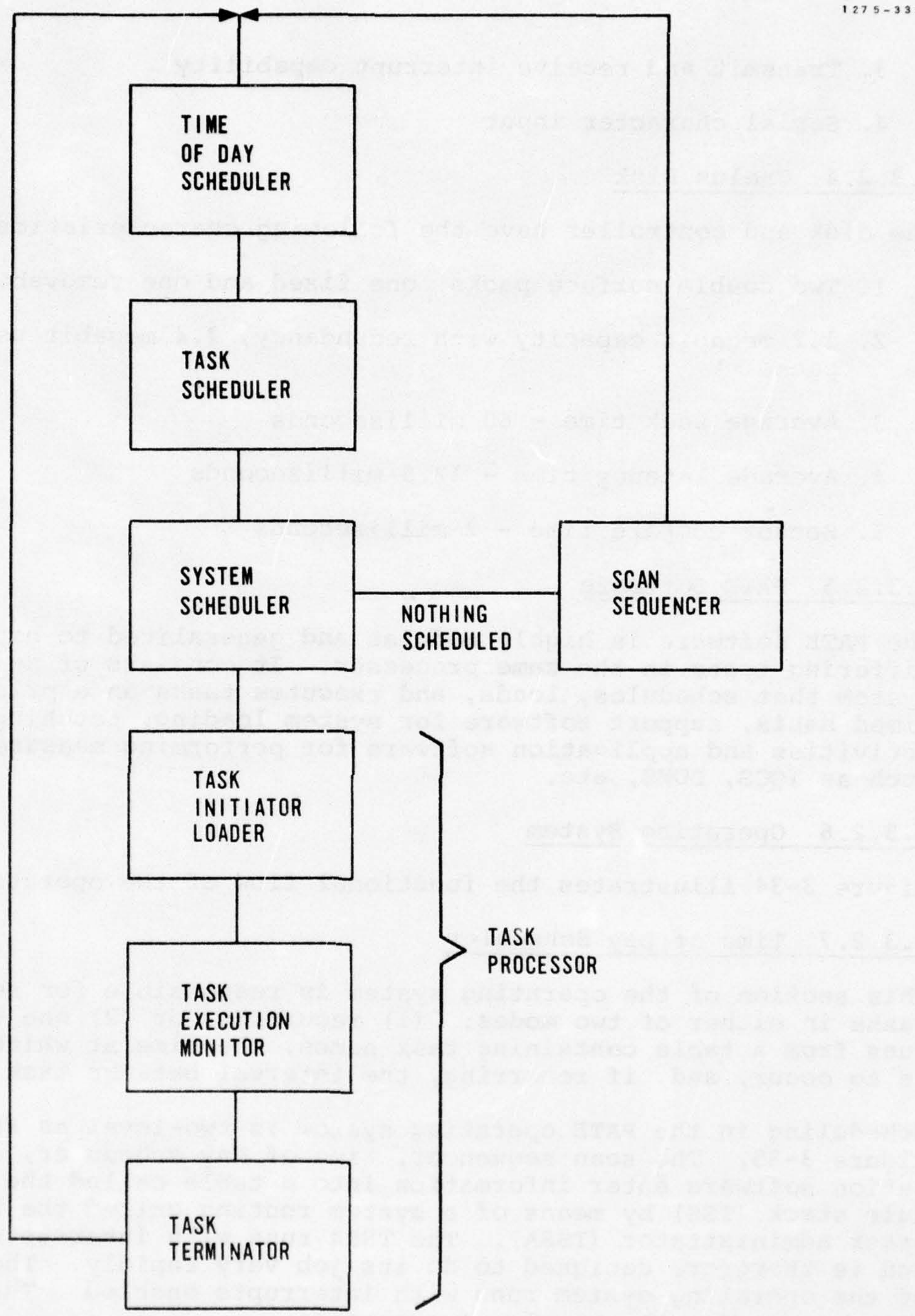

FIGURE 3-34. PATE OPERATING SYSTEM

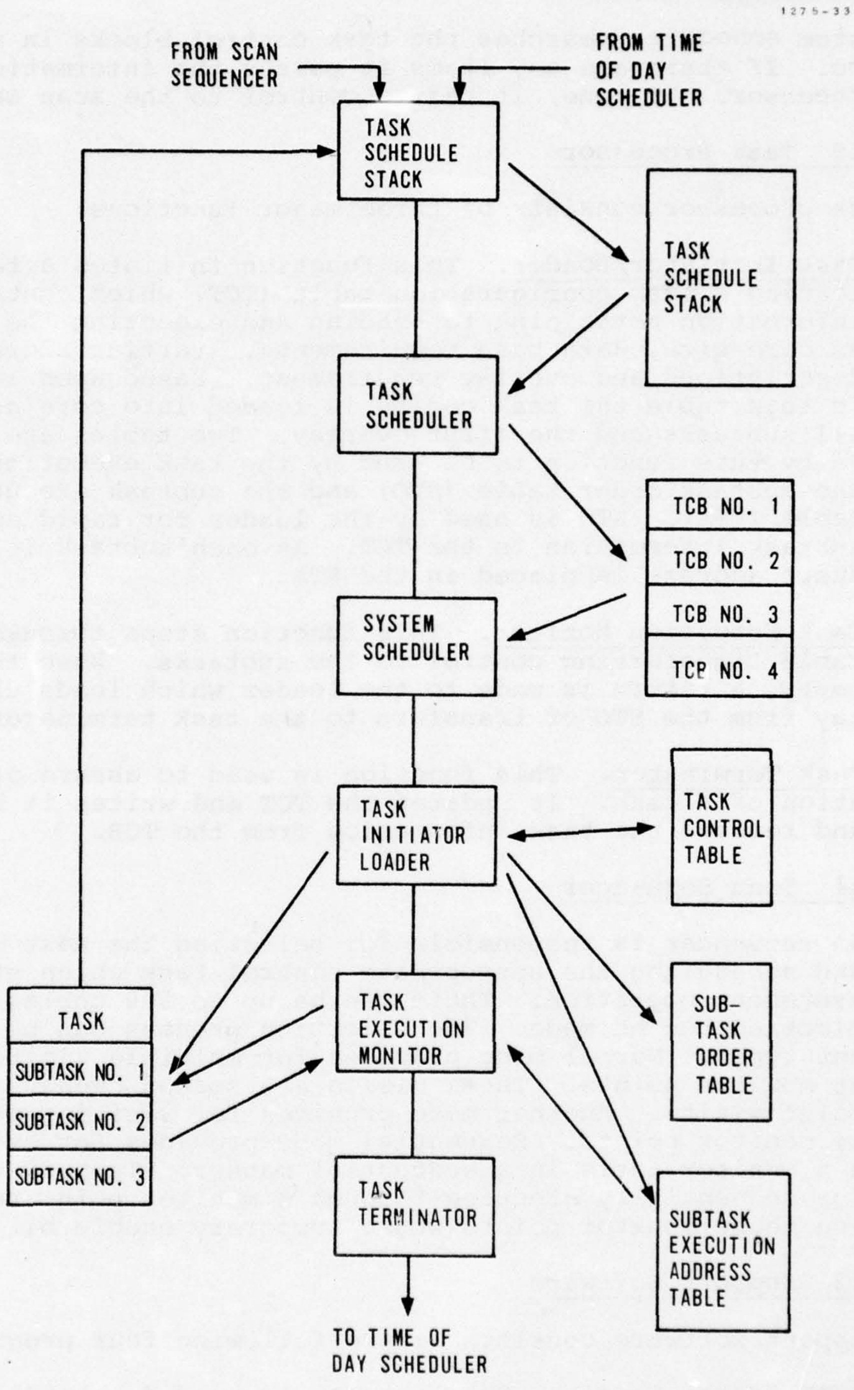

FIGURE 3-35. PATE TABLE FUNCTIONS

3.3.2.9 System Scheduler

The system scheduler searches the task control blocks in priority sequence. If there are any items it passes the information to the task processor. If none, it passes control to the scan sequencer.

3.3.2.10 Task Processor

The task processor consists of three major functions:

1. Task Initiator/Loader. This function initiates a task by first loading a task configuration table (TCT) which contains all information pertaining to loading and executing the task such as core size, data base requirements, starting address, subtask descriptions and overlay requirement. Based upon information in this table the task coding is loaded into core as well as all subtasks and the first overlay. Two tables are also generated by this function to be used by the task execution monitor, the subtask order table (STO) and the subtask execution address table (STA). STO is used by the loader for rapid access to subtask information in the TCT. As each subtask is loaded its start address is placed in the STA.

2. Task Execution Monitor. This function steps through the STA table transferring control to the subtasks. When the table is empty, a return is made to the loader which loads the next overlay from the STO or transfers to the task terminator.

3. Task Terminator. This function is used to assure orderly termination of a task. It updates the TCT and writes it back to disk and removes the task information from the TCB.

3.3.2.11 Scan Sequencer

The scan sequencer is responsible for selecting the next monitor point and scheduling the appropriate control task which starts off the measurement operation. There can be up to 100 tables from which this selection can be made. The selection process can be one of four different types. Normal mode provides for multiple visits of high interest monitor points. These visits are spaced evenly among the other point visits. Another mode provides for visiting only high priority monitor points. Sequential mode provides for stepping through a monitor table in a sequential manner. Temporary mode provides for sequentially stepping through a monitor point table and selecting those monitor points whose temporary enable bit is on.

3.3.2.12 Support Software

PATE support software consists of the following four programs:

1. PATE System Loader. This program is used for loading programs from paper tape or cassette tapes onto the Caelus disk.

2. Disk Utility Program. This is an off-line utility program for disk maintenance. It provides the following capabilities:

   a. Format the removable or fixed disk

   b. Initialize the disk directory

   c. Copy the removable disk pack to the fixed disk pack

   d. Copy the fixed disk pack to the removable disk pack

   e. Print the disk directory on the ASR-37

   f. Load the resident core executive program

3. Patch. This is a program which allows an operator to inspect and/or change a program while in core using the ASR-37.

4. Debug. This is a program that provides additional debug and data analysis capability.

A more detailed description of the support software can be found in the PATE Part I specification.

3.3.2.13 Application Software

The current applications software consists of the following major tasks:

1. Time dependent monitor table executor
2. End of scan schedular
3. Common trend algorithm
4. Summary generator
5. IQCS measurements
6. OQCS measurements
7. DDMS measurements
8. MSMS measurements
9. Nucleus interaction
10. Operator interaction
11. Data base control

3.3.2.14 PATE Timing Analysis

Table 3-4 shows a comparison of PATE scan timing with an IQCS with no disk. Worst case assumes five tasks, all overlaid and one channel table load. Average case assumes one subtask overlaid with one channel table in memory.

TABLE 3-4. PATE AND IQCS COMPARISON

IQCS (no disk)	5 sec/channel
PATE (worst case)	5.59 sec/channel
PATE (average case)	5.33 sec/channel
PATE (best case)	5.15 sec/channel

3.3.3 PATE Software Adaptations

In order to add the capability of nodal control monitoring of the FKV network to the existing PATE software, the following is required:

a. Addition of a command to PATE operator interaction to initiate nodal control monitoring.

b. Modification of the existing single line controller interrupt routines to handle MAC and MAD outputs and inputs.

c. Addition of software modules to provide nodal control monitoring. See Figure 3-36.

d. Addition of software modules to provide operator interaction for nodal control monitoring. See Figure 3-37.

3.3.3.1 Start Nodal Control Scan Command

The command mnemonic NC will be added to the existing list of PATE operator interaction commands. When this command is given the nodal control monitor software will be loaded and started.

3.3.3.2 Single Line Controller Interrupt Routines

The existing single line controller input and output interrupt routines will be modified to transfer data from a line output buffer to the MAC or MAD and receive data from these devices and store it in a line input buffer. Figures 3-38 and 3-39 illustrate the functional operation of these routines. (NOTE: All software illustrations are presented on pages 179 through 205.)

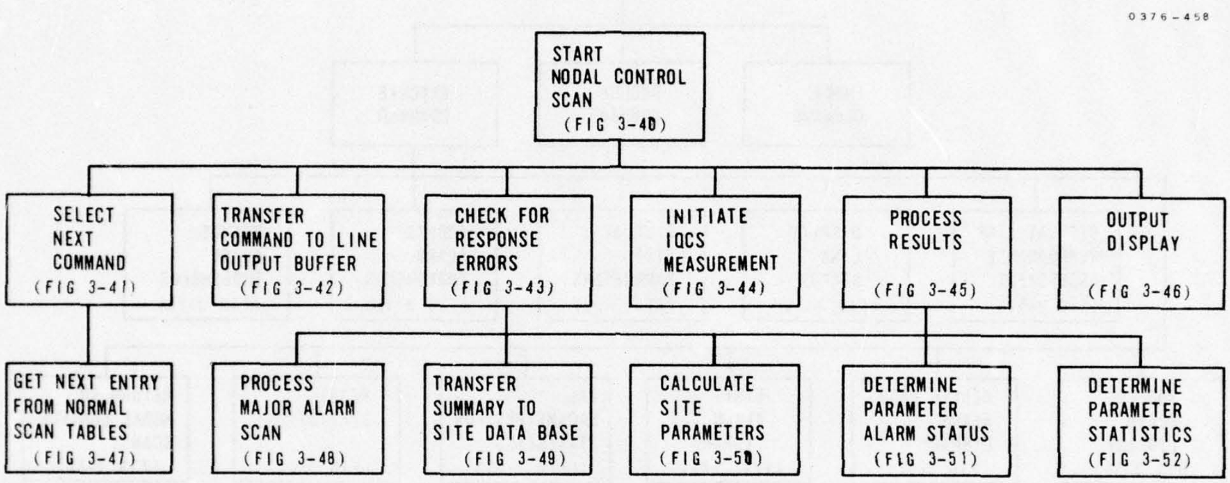

FIGURE 3-36. NODAL CONTROL SCAN HIERARCHY (INPUT/PROCESS/OUTPUT DATA)

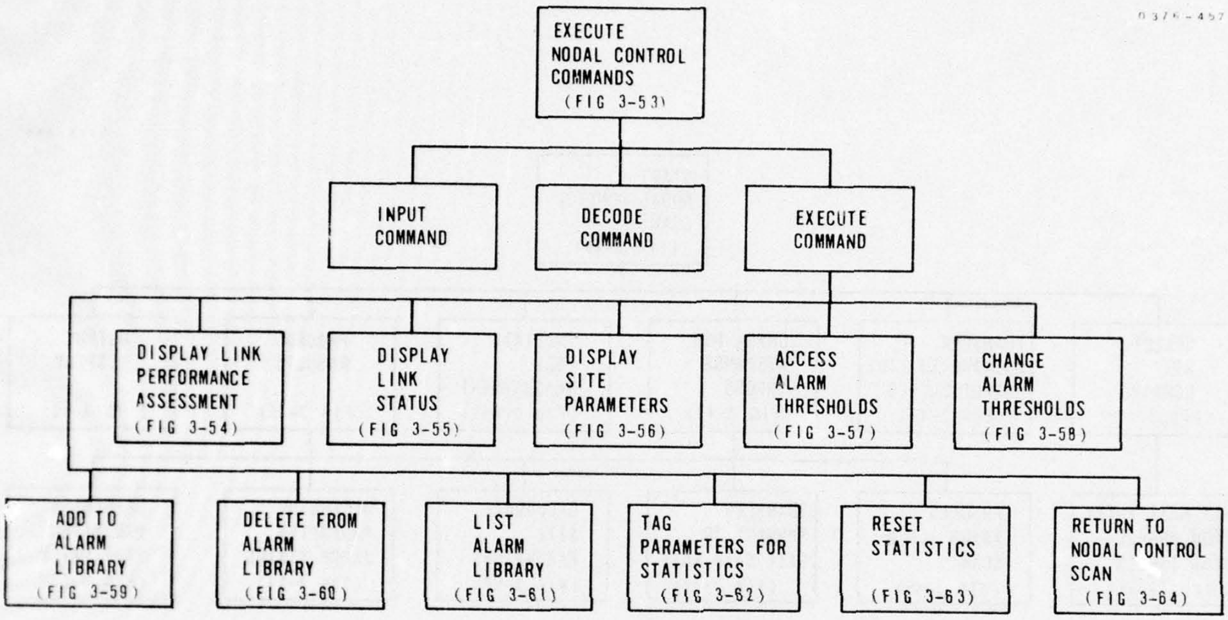

FIGURE 3-37. NODAL CONTROL COMMANDS HIERARCHY (OPERATOR INTERACTION)

3.3.3.3 Nodal Control Monitoring Software

The Nodal Control Monitoring Software consists of modules for inputting MAC, MAD, and IQCS data, processing this data, and outputting it in an easily understood form. It is so organized that data transfer occurs in conjunction with processing. Figure 3-40 illustrates the functional flow. Data input is accomplished by the following modules.

1. SELECT NEXT COMMAND (Figure 3-41)
2. TRANSFER COMMAND TO LINE OUTPUT BUFFER (Figure 3-42)
3. CHECK FOR RESPONSE ERRORS (Figure 3-43)
4. INITIATE IQCS MEASUREMENT (Figure 3-44)
5. PROCESS RESULTS (Figure 3-45)
6. OUTPUT DISPLAY (Figure 3-46)

After the initial command is selected and transferred to the line output buffer, a loop is entered in which the response message is checked for validity. The next command is selected and transferred to the output buffer and the results of the previous command are processed. If, during processing, it is determined that output should occur, a call is made to the OUTPUT DISPLAY MODULE. This loop is contained until interrupted by the operator.

3.3.3.3.1 Command Selection

Figure 3-41 describes the functional flow of the module SELECT NEXT COMMAND. There are four selection modes: (1) retransmission, (2) major alarm scan, (3) special site table selection, and (4) normal selection.

3.3.3.3.1.1 Retransmission

If the retransmission flag is set it means that the response to the last command is in error and the command must be retransmitted.

3.3.3.3.1.2 Major Alarm Scan

The alarm summary queue is a single entry queue. If its contents are non-zero, it indicates that the normal scan process has detected a major alarm and the higher priority major alarm scan is in process. In this mode of selection, the next command will be that contained in the alarm summary queue.

3.3.3.3.1.3 Special Site Table Selection

The special site table is a command table generated whenever the operator requests a special display such as link status or site parameters. If the site table flag is set this module takes the next command from the table.

3.3.3.3.1.4 Normal Selection

The equipment alarms and parameters throughout the FKV network have been classified as major alarms, alarms, VF channel status, and digital parameters measured as analog parameters.

The following cycle times are used for nodal control monitoring as discussed in Vol III, Paragraph 2.5, Table 2-3.

1.	Major Alarms	every 30 seconds
2.	VF Channel Status	every 30 seconds
3.	Alarms	every 3 minutes
4.	Status	every 5 minutes
5.	Analog and Digital Parameters	every 15 minutes
6.	Maintenance Parameters	every 6 hours

In the normal monitoring mode, alarms, and parameters are input in the above cycle times and the status reported with the system overview display. In the mode of selection, the next command is determined so as to meet the above cycle time criteria. This is done in a module called GET NEXT COMMAND FROM NORMAL SCAN TABLES (Figure 3-47).

3.3.3.3.1.5 Command Format

The output of the SELECT NEXT COMMAND module is a two-word command encoded as shown in Figure 3-41. These two words contain all of the information required to format a command for the MAC or MAD, process the results and output a display, if required. The from and to channel numbers are included in order to provide the capability of scanning multiple channels with a MAC.

3.3.3.3.1.6 Command Transmission

The transmission of commands to the MAC or MAD is accomplished in module TRANSFER COMMAND TO LINE OUTPUT BUFFER (Figure 3-42) and the controller input interrupt module (Figure 3-38). The

TRANSFER COMMAND TO LINE OUTPUT BUFFER module decodes the command and places the appropriate string of ASCII characters in the line output buffer. It then enables the controller input interrupt which causes an entry into the processing routine whenever the controller is ready for another character. When entered, the processing routine outputs a character to the controller. When all characters have been output, the controller interrupt is disabled.

3.3.3.3.2 Response Error Checking

Data is received from the MAC or MAD by the controller output interrupt module (Figure 3-39). An interrupt occurs when the controller has a character. This causes an entry into the processing module which stores the character in the line input buffer and checks for end of message. When this occurs, an end of message flag is set. The module CHECK FOR RESPONSE ERRORS (Figure 3-43) waits until the end of message flag is set. When this occurs and the checksum and echo back response is okay, the message is transferred to the results buffer for further processing. If the checksum or echo back is in error, the retransmit flag is set. If retransmission has already occurred three times, then a message is given to the operator indicating that the MAC or MAD is inoperative.

3.3.3.3.3 IQCS Measurements

Module INITIATE IQCS MEASUREMENT (Figure 3-44) provides the control linkages required when a VF channel status command is selected. This module schedules the IQCS measurement task then it schedules the START NODAL CONTROL SCAN module with a special entry for processing the results when it is executed.

3.3.3.3.4 Results Processing

After data is received and found to be error free, it is processed by module PROCESS RESULTS (Figure 3-45). Results can be obtained from MAD poll command, MAD alarm summary command, MAC dc voltage measurements or an IQCS measurement.

3.3.3.3.4.1 MAD Poll Response

The MAD is continuously receiving alarm scanner information describing the status of alarms on a particular scanner. Alarms on a scanner may be "wired" as major alarms. If the MAD determines that the status of major alarms on a scanner has gone from no major alarms to one or more major alarms, it sets an

alarm scanner major alarm indicator. There is an indicator for each alarm scanner connected to the MAD (a maximum of 10). The response to a MAD poll command will be a positive acknowledgment (the character +) if none of the major alarm indicators have changed since the last poll command. If any indicators has changed, then the response is the state (1 or 0) of all indicators.

The software responsible for processing MAD poll responses maintains the status of the major alarm indicators in core. If a positive acknowledgment is received and the major alarm status word is zero, no further processing is required. However, if it is non-zero, a major alarm scan is entered. In a major alarm scan the status of all alarms on all alarm scanners whose major alarm indicators are set is obtained. The determination of the next alarm scanner is done in module PROCESS MAJOR ALARM SCAN (Figure 3-48).

If an indicator status update is received in response to a MAD poll command, this information is used to update the in core status word.

3.3.3.3.4.2 Alarm Summary Response

The response to an alarm summary command is the status of all alarms on the specified alarm scanner. Processing for this response involves transferring the data to the site data base. This is done in module TRANSFER SUMMARY TO SITE DATA BASE (Figure 3-49). If a major alarm scan is in progress, the next alarm scanner is determined and placed in the alarm summary queue.

3.3.3.3.4.3 MAC Voltage Response

The response to a MAC voltage measurement is first converted to floating point and transferred to the site data base. Parameters are then calculated in module CALCULATE SITE PARAMETERS (Figure 3-50). The alarm status, if required, is then determined in module DETERMINE PARAMETER ALARM STATUS (Figure 3-51). If trending is indicated, then mean and standard deviations are calculated in module CALCULATE PARAMETER STATISTICS (Figure 3-52).

3.3.3.3.4.4 IQCS Response

The response to an IQCS measurement is the alarm status (Red, Amber, Green) of the measured VF channel. The IQCS measurement task transfers this information to disk. When the nodal control

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ATEC DIGITAL ADAPTATION STUDY. VOLUME II. ATEC APPLICABILITY AN--ETC(U)
OCT 76 T R ARMSTRONG, A K BLOUGH F30602-75-C-0882
UNCLASSIFIED 476-13656-VOL-2 RADC-TR-76-302-VOL-2 NL

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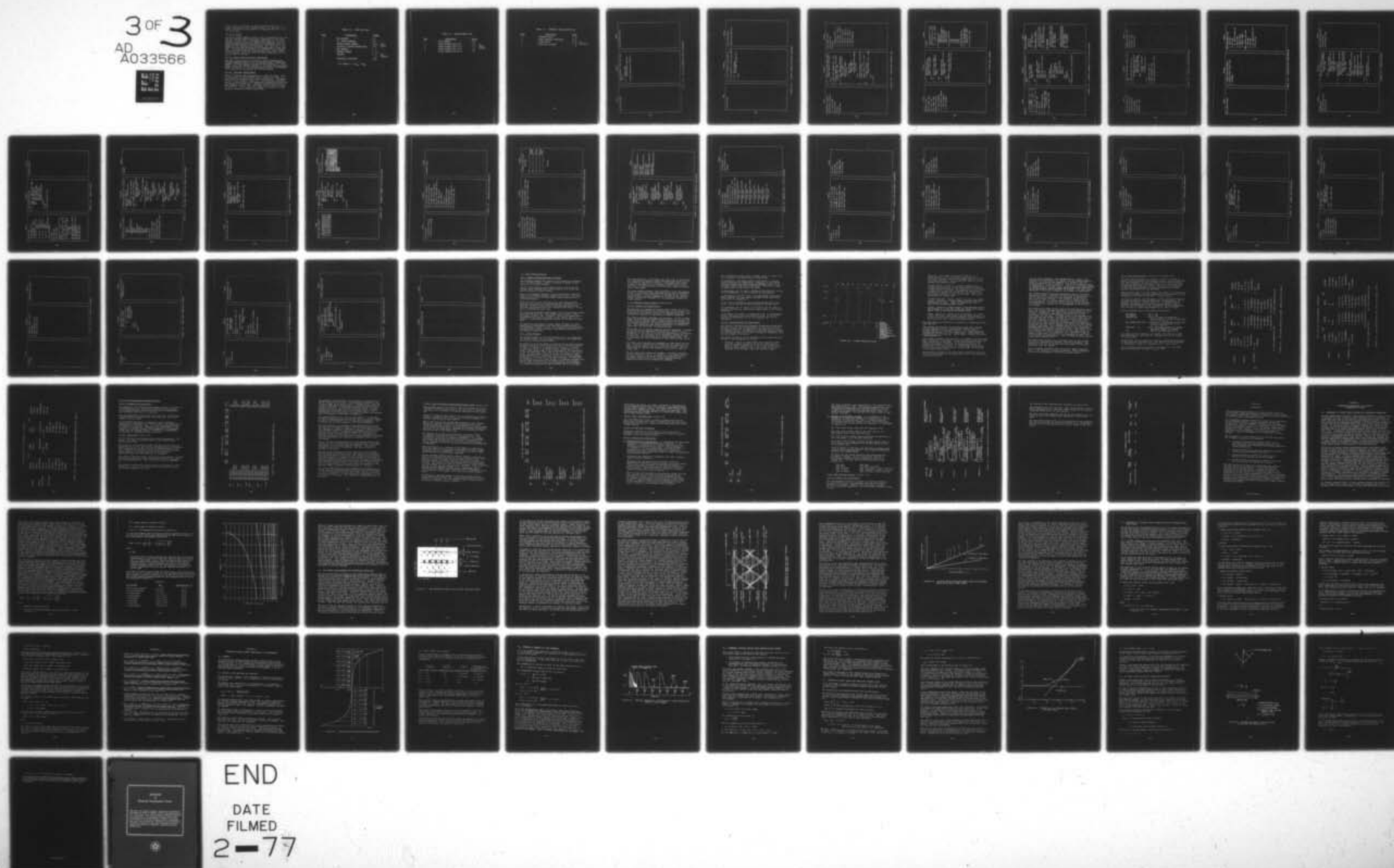

END
DATE
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2-77

monitor task is reloaded, the PATE executive transfers the stored information to an internal buffer. The PROCESS RESULTS module has access to this buffer and transfers the data to the site data base.

3.3.3.3.5 Output

The module OUTPUT DISPLAY (Figure 3-46) is responsible for reading the required display from disk, formatting it, and transferring it to the CRT. This module will output one of eight displays, depending upon the display type employed. The site table contains anywhere from one to six site identifiers, depending on the display being generated. For each site in the table, the site data base and a site display map is read from disk. The display map indicates the parameter to be obtained from the data base and the location where it is to be placed on the display. After all sites have been processed, the display is sent to the CRT.

3.3.3.4 Nodal Control Operator Interaction

The Nodal Control Operator Interaction module EXECUTE NODAL CONTROL COMMANDS (Figure 3-53) is scheduled when a common PATE command is entered with the characters NC preceding it. This module inputs the command, decodes it, and calls the appropriate module to process it. The HIPO diagrams (Figures 3-54 through 3-64) describe the processing done by each module.

3.3.3.5 Data Base Requirements

Table 3-5 defines the requirements of a site data base. Item 4, the pointer to alarm scanner data, points to an item in a disk file that contains alarm scanner information. The format of this item is shown in Table 3-6. The conversion indicator, item 8, is used to get to the appropriate computation algorithm for parameter calculations. Parameter values are stored in a site parameter table. The item format of this table is shown in Table 3-7. If a parameter is tagged for statistic, a disk sector is reserved to store history data.

TABLE 3-5. SITE DATA BASE

Item	Description	Words	
1	MAD ADDRESS	1/2	
2	NO. ALARM SCANNERS	1/2	
3	ALARM SCANNER NUMBER	1/2	Per Alarm
4	POINTER TO ALARM SCANNER DATA	1/2	
5	MAC ADDRESS	1	Per Channel
6	CHANNEL NUMBER	1	
7	VOLTAGE	2	
8	CONVERSION INDICATOR	1/2	

$$\text{NO. WORDS} = 2 + N_{AS} + 4N_{CH}$$

TABLE 3-6. ALARM SCANNER DATA

Item	Description	Words	
1	TIME UPDATED	1	Per Alarm Scanner
2	ALARM SCANNER BITS 0-15	1	
3	ALARM SCANNER BITS 16-31	1	
4	ALARM SCANNER BITS 32-47	1	
5	ALARM SCANNER BITS 48-49	1	

TABLE 3-7. PARAMETER TABLE DESCRIPTION

Item	Description	Words	
1	PARAMETER VALUE	1	Per Parameter
2	ALARM THRESHOLD INDICATOR	1/2	
3	ALARM STATUS	1/2	
4	STATISTICS POINTER	1	

Input	Process	Output
Line output buffer	1. Get a character from line output buffer 2. If Buffer empty Disable input interrupt 3. Output character to controller	System interrupt mask

FIGURE 3-38. PROCESS CONTROLLER INPUT INTERRUPTS

Input	Process	Output
Data character	1. Input character from controller 2. Put character in line input buffer 3. If End of message Set message received flag Else	Line input buffer Message received flag

FIGURE 3-39. PROCESS CONTROLLER OUTPUT INTERRUPT

Input

MAC/MAD/IQCS commands
MAC/MAD/IQCS responses
Line input buffer
Results buffer
Displays
Display maps

Process

```
1. If    Return from IQCS measurement
         Process results (Fig.3-45)
   Else
2. Select next command (Fig. 3-41)
3. Transfer command to line output
     buffer (Fig. 3-42)
4. Do    Until operator interrupts
5.       Check for response errors
           (Fig. 3-43)
6.       Select next command
           (Fig.3-41)
7.       If   IQCS channel
              Process results
                (Fig. 3-45)
              Initiate IQCS measurement
                (Fig.3-44)
         Else
8.      Transfer command to line output
        buffer (Fig. 3-42)
9.      Process results (Fig. 3-45)
10.     If output flag set
              Output display (Fig. 3-46)
        Else
11. End Do
```

Output

Line output buffer
Site data base
Displays:

1. System Overview
2. Link Status - Level 1
3. Link Status - Level 2
4. Link PA - Level 1
5. Link PA - Level 2
6. Link PA - Level 3
7. Link PA - Level 4
8. Site Parameters

FIGURE 3-40. START NODAL CONTROL SCAN

Input

Retransmit flag

Alarm summary queue

Site table flag

Site command table

Normal scan tables:

a. Alarm commands

b. Maintenance commands

c. Analog commands

d. IQCS commands

Process

1. If Retransmit flag set
   Reset retransmit flag
   Command = Last command
   Else
2. If Entry in alarm summary Q
   Command = Alarm summary Q entry
   Else
3. If Site table flag set
   Command = Next entry in-site command table
   Else
4. Command = Next entry from normal scan tables (Fig.2.3-8)

Output

Command

(1)	(2)		(3)
(4)			(5)

(1) Command Type
- 0-MAD Poll
- 1-MAD Alarm Summary
- 2-MAC DC Voltage
- 3-MAC Self-Test
- 4-IQCS Channel

(2) Site Identifier
- 0-SGT
- 1-VHN
- 2-STB
- 3-SWN
- 4-KSL
- 5-HDG

(3) MAC/MAD Address

(4) Alarm Scanner (MAD)
From Channel (MAC)
Channel No. (IQCS)

(5) To Channel (MAC)

FIGURE 3-41. SELECT NEXT COMMAND

Input

Command

(1)	(2)	▨	(3)
(4)			(5)

(1) → Command Type

(2) → Site

(3) → MAC/MAD Address

(4) → Alarm Scanner (MAD)
From Channel (MAC)

(5) → To Channel (MAC)

Process

```
1. Extract Addresses and convert to
   ASCII
2. If   MAD poll command
        Store MAD address
        Store "$"
   Else
3. If   Alarm summary command
        Store MAD address
        Store "A"
        Store alarm scanner address
        Store "\"
        Store "G"
   Else
4. If   MAC command
        Store MAC address
        Store "D1/"
        Store from channel
        If   To Channel ≠0
             Store "/"
             Store to channel
             Store "\"
             Store "G"
        Else
        Store "\"
        Store "G"
   Else
5. Enable controller input interrupt
```

Output

MAD Poll Command

(3)	$

(3) - MAD Address

Alarm Summary Command

(3)	A	(4)	\	G

(3) - MAD Address
(4) - Alarm Scanner Address

MAC Commands

(3)	D	1	/	(4)	\	G

(3) - MAC Address
(4) - From Channel

or

(3)	D	1	/	(4)	/	(5)	\	G

(3) - MAC Address
(4) - From Channel
(5) - To Channel

FIGURE 3-42. TRANSFER COMMAND TO LINE OUTPUT BUFFER

Input

- Message received flag
- Checksum character
- Computed checksum
- Output command
- Retransmit flag
- Retransmit count

Process

```
1. Wait until message received flag
   set
2. Reset message received flag
3. If    Checksum or echo back error
         If    Retransmit count >3
               Output error message
               Reset retransmit flag
         Else
               Increment retransmit
                 count
               Set retransmit glag
   Else
4. Retransmit count = 0
5. Reset retransmit flag
6. Move message to results buffer
```

Output

- Message received flag
- Retransmit flag
- Retransmit count
- Results buffer

FIGURE 3-43. CHECK FOR RESPONSE ERRORS

Input	Process	Output
IQCS channel number	1. Schedule IQCS measurement 2. Schedule nodal control scan 3. Terminate	IQCS measurement task a. Task name b. SID code c. No. control words (3) d. Entry level e. Output vector f. Channel number Nodal control scan task a. Task name b. SID code c. No. control words (1) d. Entry level

FIGURE 3-44. INITIATE IQCS MEASUREMENTS

Input	Process	Output

Command type
Major alarm scan flag
Results buffer
	1. If MAD poll response
	   If Positive acknowledgment
	      Process major alarm scan (Fig. 3-48)
	   Else
	   If Major alarm summary
	      Generate new major alarm status word
	      Process major alarm scan (Fig. 3-48)
	2. If MAD alarm summary
	   Transfer summary to site data base (Fig. 3-49)
	   If Major alarm scan flag set
	      Process major alarm scan (Fig. 3-48)
	   Else
	3. If MAC voltage response
	   Transfer voltage to site data base
	   Calculate site parameters (Fig. 3-50)
	   Determine parameter alarms (Fig. 3-51)
	   Calculate parameter statistics (Fig. 3-52)
	Else
	4. If IQCS measurement
	   Store channel alarm status
		Major alarm status word
		Site data base
		Alarm summary queue

FIGURE 3-45. PROCESS RESULTS

Input	Process	Output
Display type: 0-System Overview 1-Link Status - Level 1 2-Link Status - Level 2 3-Link PA - Level 1 (Rx-Radio) 4-Link PA - Level 2 (Rx-TI-4000) 5-Link PA - Level 3 (Rx-T1WB1) 6-Link PA - Level 4 (Availability) 7-Site Parameters Site table Site data base Site display map [(1) | (2)] [(3) | (4) | (5)] (1) Start position in word 0 - left 1 - right (2) Word location in display (3) Type conversion (4) No. characters in field (5) Parameter No. Unformatted display	1. Read display from disc 2. Do Until no items in-site table Read site data base Read site display map Do Until no map items Get field item Convert to ASCII Transfer to display End Do End Do 3. Transfer display to CRT	Formatted display

FIGURE 3-46. OUTPUT DISPLAY

Input	Process	Output
Command select indicator: 0 - MAD Poll Alarms IQCS Analog Parameters 1 - MAD Poll Alarms IQCS Maintenance Analog 2 - MAD Poll Alarms IQCS Status Analog Cycle count Alarms command table IQCS channels table Analog parameters table Maintenance parameters table	1. Generate command select indicator 2. Case (Last Command) (MAD Poll) - Get next alarm command (Alarm) - Get next IQCS channel 3. Case (Command Select Indicator) (0) - If Maximum analog commands Generate MAD poll command Else Get next analog command (1) - Case (Last Command) (IQCS) - Get next maintenance command (Maintenance) If Maximum analogs Generate MAD poll command Else Get next analog command (2) - Case (Last Command) (IQCS) - Generate status command (Status) If Maximum analogs Generate MAD poll command Else Get next analog command	Command

FIGURE 3-47. GET NEXT COMMAND FROM NORMAL SCAN TABLES

Input	Process	Output
Major alarm status word	1. If Major alarm status word ≠ 0 Set major alarm scan flag Generate alarm scanner address Generate alarm summary command Store command in alarm summary queue Else 2. Reset major alarm scan flag	Major alarm scan flag Alarm summary queue

FIGURE 3-48. PROCESS MAJOR ALARM SCAN

Input

Result buffer (ASCII)

(3)	A	(4)	\	G	C_R	L_F	0	0
0	1	1	0	0	1	0	1	
							\	LRC

Process

```
1. Read site data base
2. Do    Until "\" encountered in
         Result buffer
         Get next character
         If    Character = 0 and
                 bit ≠ 0
               Set bit = 0
               Set output flag
         Else
         If    Character = 1 and
                 bit = 1
               Set bit = 1
               Set output flag
         Else
3. End Do
```

Output

Output flag

Site data base (binary)

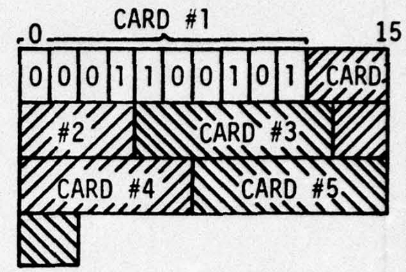

FIGURE 3-49. TRANSFER SUMMARY TO SITE DATA BASE

Input	Process	Output
Site data base a. Conversion indicator b. Measured dc voltages	1. Case (Conversion Indicator) (1) RSL and RSL availability (2) TI-4000 frame errors (3) TI-4000 control reframes (4) Eye noise, amplitude, bursts (5) T1WB1 frame errors (6) T1WB1 reframes (7) RSL/noise (8) Reframe/ RCVR squelch (9) Reframe/eye bursts (10) Error rate availability (11) Link bit error rate	Parameter values

FIGURE 3-50. CALCULATE SITE PARAMETERS

Input	Process	Output
Alarm threshold indicator Red high threshold (RH) Amber high threshold (AH) Center green value (CG) Amber low threshold (AL) Red low threshold (RL)	1. Read alarm threshold 2. Determine parameter alarm status 3. Store status in site data base	Parameter alarm status Red High RH Amber High AH Green CG AL Amber Low RL Red Low

FIGURE 3-51. DETERMINE PARAMETER ALARM STATUS

Input	Process	Output
Parameter value Disc storage pointer	1. If Parameter tagged for statistics Store in hourly values If One hour elapsed Calculate mean Calculate standard deviation Store mean in daily values Else If 24 daily values Calculate mean Calculate standard deviation Store mean in monthly values Else If 30 monthly values Calculate mean Calculate standard deviation Store mean in 30 month values Else If 30-30 month values Calculate mean Calculate standard deviation Else Else	Hourly values Hourly mean Hourly standard deviation Daily values Daily mean Daily standard deviation Monthly values Monthly mean Monthly standard deviation 30-month mean 30-month standard deviation

FIGURE 3-52. CALCULATE PARAMETER STATISTICS

Input	Process	Output
Keyboard input buffer Operator command: a. NC b. Command mnemonic c. Arguments	1. Input command 2. Decode command 3. Case (Command Mnemonic) (LP)-Link PA (Fig. 3-54) (LS)-Link Status (Fig. 3-55) (SP)-Site parameters (Fig. 3-56) (AA)-Access alarm thresholds (Fig. 3-57) (CA)-Change alarm thresholds (Fig. 3-58) (AL)-Add to alarm library (Fig. 3-59) (DL)-Delete from alarm library (Fig. 3-60) (LL)-List alarm library (Fig. 3-61) (TS)-Tag for statistics (Fig. 3-62) (RS)-Reset statistics (Fig. 3-63) (RN)-Return to nodal scan (Fig. 3-64)	Site data base Alarm threshold library Displays

FIGURE 3-53. EXECUTE NODAL CONTROL COMMANDS

Input	Process	Output
Arguments a. Site #1 b. Site #2 c. Display level	1. Put Site #1 in site table 2. Put Site #2 in site table 3. Display type = level +2 4. Generate site command table 5. Set site table flag 6. Start nodal control scan	Site table Display type Site table flag Site command table Link PA display

FIGURE 3-54. DISPLAY LINK PERFORMANCE ASSESSMENT

Input	Process	Output
Arguments	1. Put Site #1 in site table	Site table
a. Site #1	2. Put Site #2 in site table	Display type
b. Site #2	3. Display type = level	Site table flag
c. Display level	4. Generate site command table	Site command table
	5. Set site table flag	Link status display
	6. Start nodal control scan	

FIGURE 3-55. DISPLAY LINK STATUS

Input	Process	Output
Arguments a. Site	1. Put site in site table 2. Display type = 7 3. Generate site command table 4. Set site table flag 5. Start nodal control scan	Site table Display type Site table flag Site command table Site parameter display

FIGURE 3-56. DISPLAY SITE PARAMETERS

Input	Process	Output
Arguments a. Site b. Parameter No. Alarm threshold indicator	1. Read site parameter item 2. Read alarm thresholds 3. Convert to ASCII 4. Output to CRT	Indicator and alarm Threshold values

FIGURE 3-57. ACCESS ALARM THRESHOLDS

Input	Process	Output
Arguments a. Site b. Parameter No. c. Threshold index	1. If Index in library Read parameter item Enter index Write new parameter item Else 2. Error - undefined index	Parameter item

FIGURE 3-58. CHANGE ALARM THRESHOLDS

Input	Process	Output
Arguments a. Index b. Red high threshold c. Amber high threshold d. Center green value e. Amber low threshold f. Red low threshold	1. Read library record 2. If Index not in use Enter threshold values Write library record Else 3. Error - index being used	Updated library record Error message

FIGURE 3-59. ADD TO ALARM THRESHOLD LIBRARY

Input	Process	Output
Arguments a. Index	1. Determine library record 2. Read record 3. Clear threshold items 4. Write library record	Updated library record

FIGURE 3-60. DELETE FROM ALARM THRESHOLD LIBRARY

Input	Process	Output

Arguments
  none
	1. Do Until end of library
	        Read library record
	        Do Until end of record
	            If Values present
	                Convert to ASCII
	                List values
	        Else
	        End Do
	    End Do
		Complete list of alarm
		  threshold value

FIGURE 3-61. LIST ALARM THRESHOLD LIBRARY

Input	Process	Output
Arguments a. Site b. Parameter No.	1. Read parameter item 2. If Already tagged Ignore request Else 3. Determine next available disc record 4. If No record available Error - statistics storage filled Else 5. Read record 6. Clear record 7. Place record No. in parameter item 8. Write parameter item	Updated parameter item Error messages

FIGURE 3-62. TAG PARAMETERS FOR STATISTICS

Input	Process	Output

Arguments
  a. Site
  b. Parameter No.
  c. Item No.
  d. Value
	1. Read parameter item
	2. If Statistics pointer ≠ 0
	        Read statistics record
	        Do Until blank item No.
	              Input item No. and value
	              Enter value
	        End Do
	        Write statistics record
	    Else
	3. Error - No statistics for
	    parameter.
		Updated parameter item

FIGURE 3-63. RESET PARAMETER STATISTICS

Input	Process	Output
Arguments none	1. Schedule nodal control scan	None

FIGURE 3-64. RETURN TO NORMAL NODAL CONTROL SCAN

3.4 ATEC OUTPUTS/DISPLAYS

3.4.1 Types and Relationships of Outputs

The standard displays and outputs of the system are organized in a way which allows a logical unfolding of detail in the analysis of a system problem.

The top level display is the Sudden Service Failure Sensing System, using standard ATEC alarm displays, with visual and aural alarming of service failure.

Next in the display hierarchy is the System Overview Display, which is the display normally resident on the CRT. This provides the next layer of detail about system conditions on a system wide basis.

Below the level of the overview is the link status display. Data for this display is collected whenever the display is requested; it shows current alarm status and parameter values for both directions of the link, including site alarms. A display is provided for each link.

For long term performance assessment, the link performance assessment displays are used. They encompass three pages: radio, multiplex (T1-4000), and 1.544 Mb/s. These allow comparison of performance over varying periods of time ranging back to 30 months. A performance assessment display is available for each link.

For reporting and display of power supply voltages and other parameters as designated by the monitoring system operator, a site parameter display is used. This display shows measurements, alarming limits, historical means, and standard deviations of the measured parameters.

3.4.2 Alarm Displays

The primary purpose of the alarm display units, as recommended for the FKV system, is to provide a vehicle for the Sudden Service Failure Sensing System (SSFSS).

The manner in which the SSFSS is organized on the alarm scanners, together with the relevant portions of the FKV network diagram, is shown in Figures 3-17 through 3-22 of Volume I. Service failure will result in an audible alarm, illumination of the bright "major alarm" lamp on the alarm scanner, and illumination of the red individual alarm lamp on the left side of the alarm cards. By this means, a service failure is brought to human cognizance within 3.8 seconds for sites with 50 alarms maximum and within 3.1 seconds for sites with 40 alarms. As discussed in Paragraph 2.1.1.1.4 of this volume, 3.8 seconds represents the time to read the contents of 50 alarms from an alarm scanner into an alarm display or MAD once synchronization is obtained. 3.1 seconds are required to read 40 alarms into an AD or MAD.

The alarm displays on the middle and right sides of the display are indicators of specific alarms and conditions which are of less severity than service failure. To maintain the visual primacy of the SSFSS, it is intended to either mask or alter the color of these indicators, so that their visual obtrusiveness is descreased.

The alarm scanner display, while available, is not the primary source of information about degradation and loss of redundancy in the network. This information is provided by the network overview and link status displays on the CRT, which, although slower, provide the information in an organized, network relatable manner.

3.4.3 Network Overview Outputs (Figure 3-65)

3.4.3.1 Purpose and Organization

The overview is a summary of network status, which can be displayed on the CRT and printed in hard copy via the printer. It is the basic CRT display, resident and updated except when other displays are required in the pursuit of specific problems.

This display embodies management by exception. It has a sparse format on which nothing appears except system aberrations. The System Overview Display gives a network picture of degradations and failures related to the affected equipment and transmission link. This method has been chosen especially to increase its impact upon the relatively untrained operator.

The columns in the display represent network geography. A column of dots is used to represent the conceptual middle of a site. Equipments to the right of the dots are elements of a link facing to the right. In the higher level equipments (AN/FRC-162 and T1-4000) the link terminates at the next column of dots. For the di-groups, the link terminates at some column of dots to the right.

The higher level equipment is segregated by rows across the display. A row is used for the "A" radio; the "B" radio; the T1-4000 protective switch, and the "A" and "B" T1-4000. The symbology used to indicate the equipment conditions is shown in Figure 3-65.

For the lower level multiplex equipment, a slightly different method of display is used. In columns, to the proper side of the column of dots, the alarm states are displayed with the equipment number, keyed to the network diagram, and the appropriate direction of transmission symbology.

For illustration of how status is shown, refer to Figure 3-65, which contains a plausible group of aberrations.

At Heidelberg, a red alarm exists in CY-104 No. 1; both or either direction of transmission. Reference to the network diagram indicates that the conjugate equipment is No. 15 at Stuttgart, which also holds a red alarm. CY-104 No. 3 holds an amber alarm in the receive direction.

At Swetzingen, the "A" radio, transmitter and receiver, on the link to Heidelberg, is out of service for maintenance.

At Koeningstuhl, the "B" radio on the Swetzingen link has an amber alarm on its power supply voltages, which affect both directions of transmission.

On the link to Stocksberg, the multiplex switch holds a red alarm, indicating that switching protection has been lost.

At Stocksberg, the "A" radio is in service; the "B" radio in standby, and both are indicating an amber alarm in the receive direction.

At Stuttgart, CY-104 No. 15, conjugate to No. 1 at Heidelberg, holds a red alarm, both directions, while No. 20 is out of service for maintenance, as is its conjugate, No. 26, at Vaihingen.

3.4.3.2 Interpretation of Alarm States

The nature of the alarm and parameter collection process which has been selected for the FKV network is such that an alarm indicates a true loss of capability, which may well be a loss of redundant backup. Degradations of measured quantities which are sufficiently severe to create a service or redundancy failure will result in an alarm.

Red alarms indicate a loss of equipment and are generated with respect to the equipments as follows:

> Radio Tx: Occurs if either radio, A or B transmit power is below a preset threshold; if the Tx pilot level is below a preset threshold; of if the Tx AFC voltage is beyond the normal control range. This alarm is the "OR" function of the RF Power, Tx Pilot, and AFC alarms.

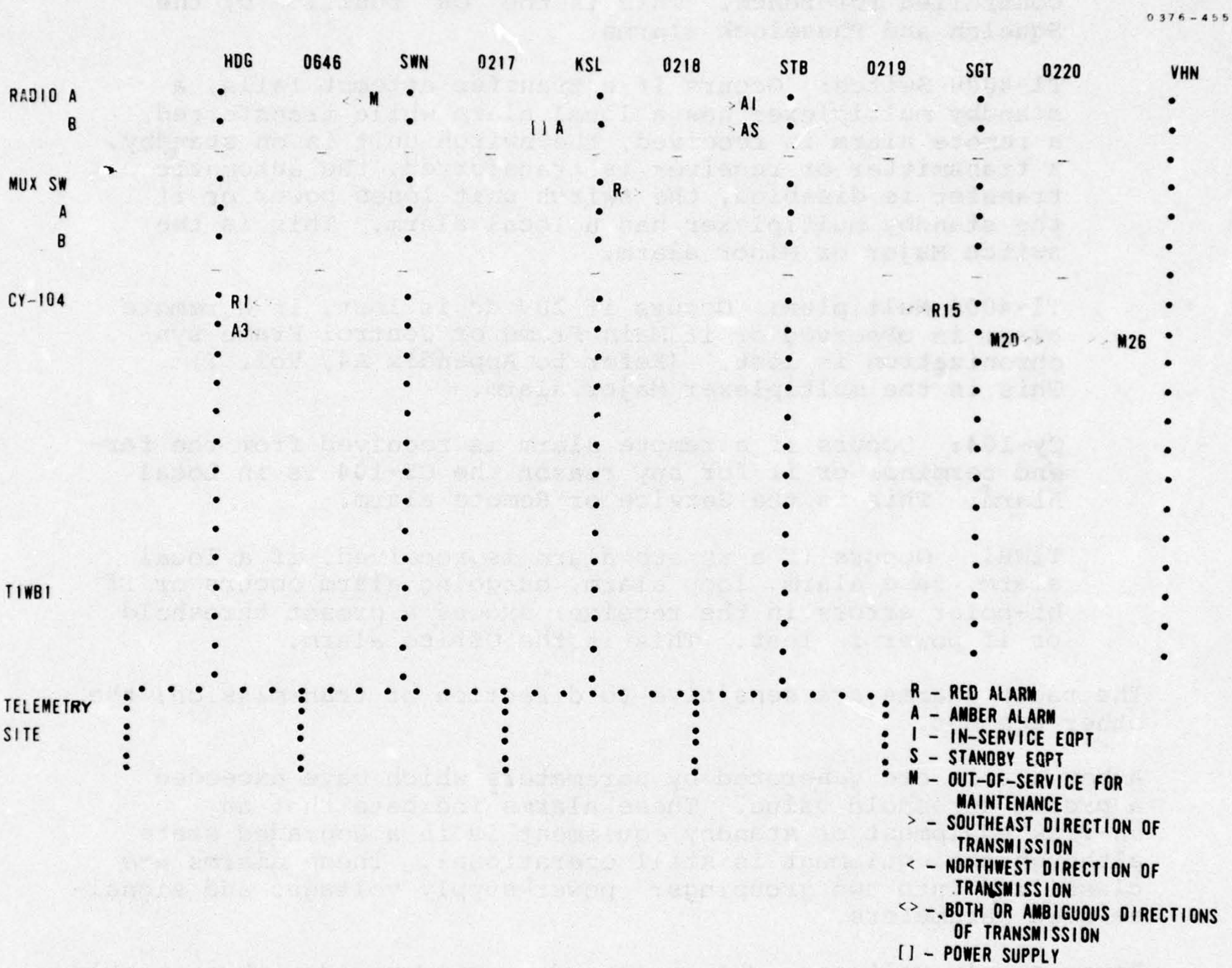

FIGURE 3-65. SYSTEM OVERVIEW OUTPUTS

Radio Rx: Occurs when the received signal level of either Radio A or B falls below a preset threshold or if the local oscillator has lost phaselock with the crystal controlled reference. This is the "OR" function of the Squelch and Phaselock alarms.

T1-4000 Switch: Occurs if a transfer attempt fails, a standby multiplexer has a local alarm while transferred, a remote alarm is received, the switch unit is on standby, a transmitter or receiver is transferred, the automatic transfer is disabled, the switch unit loses power or if the standby multiplexer has a local alarm. This is the switch Major or Minor alarm.

T1-4000 Multiplex: Occurs if 20V dc is lost, if a remote alarm is observed or if Main Frame or Control Frame synchronization is lost. (Refer to Appendix A4, Vol. I) This is the multiplexer Major alarm.

Cy-104: Occurs if a remote alarm is received from the far-end terminal or if for any reason the CY-104 is in Local Alarm. This is the Service or Remote alarm.

T1WB1: Occurs if a remote alarm is received, if a local alarm, fuse alarm, loop alarm, outgoing alarm occurs or if bi-polar errors in the receiver exceed a preset threshold or if power is lost. This is the Office alarm.

The radio alarms are sensitive to direction of transmission; the other are not.

Amber alarms are generated by parameters which have exceeded a preset threshold value. These alarms indicate that an on-line equipment or standby equipment is in a degraded state although the equipment is still operational. These alarms are classified into two groupings: power-supply voltages and signal-related parameters.

Power supply voltages, when measured, are compared with thresholds held in software in the PATE. If the threshold is exceeded, the amber indication is displayed. In the FKV equipment, power supplies are common to receiver and transmitter; hence, no directionality can be inferred. To differentiate power supply alarms from signal-related alarms, brackets ([]) are displayed for the power supply alarms.

Signal-related parameters upon which amber alarms are based are derived from equipment at the receiving end of a link and, hence, have directionality.

For the radio equipments, the recommended set of amber alarm generators are RSL margin; eye margin, and the latched receiver squelch. Both margins are compared to a threshold and the alarm generated if below threshold. The actual threshold should be determined by field experience. A value of 10 dB below nominal is suggested as an initial, trial value although the value may be set by the monitor system operator as desired. The alarm state displayed is that which existed at the instant of measurement.

The latched squelch alarm adds observation time to the margin observations since it permits the monitoring system operator to observe transient events which may otherwise go undetected due to their short duration. Its threshold, which is set at the radio and not in software, should also be determined by field experience. A value of about 5 dB above a PCM threshold corresponding to a BER of 10^{-7} is recommended for an initial, trial value.

For generation of amber alarms from the T1-4000 multiplex equipment, the latched "reframe" indication and a threshold on error counts is recommended. By means of the latches contained in the EPUT, transient reframe conditions which occur in the multiplexer are detected. The amber alarm on the multiplex will thus indicate that either a reframe has occurred within the last interscan interval or that the inferred bit error rate during the last interscan interval was excessive. The threshold on bit error rate used to generate an alarm should not necessarily be the same as that used to compute availability for performance assessment purposes. This overview output is for the purpose of bringing human attention to conditions which entail short-term investigation and possible corrective action. The threshold for this condition can also be determined by field experience; an initial value of 10^{-6} is suggested. 10^{-6} represents a BER two orders of magnitude greater than that necessary to cause loss of multiplexer synchronization. (Loss of synchronization usually occurs with a BER of 10^{-4}.)

The amber alarm condition for the T1WB1 occurs if the reframe rate (total reframes/total samples) exceeds a threshold. The threshold is set by the operator and is a result of his field experience with the system.

For VF channels associated with the CY-104, amber conditions exist if the measured VF channel parameters, exceed thresholds which may be programmed by the monitor system operator.

3.4.4 Link Status Outputs (Figures 3-66 through 3-68)

The link status displays are intended to convey a picture of current link performance and equipment status. They are obtained only when requested, and are performed by initiating a special scan of the sensors at both ends of the link. Because of this, it disrupts the normal scan cycle. Site alarms are displayed in the link status display to permit determination of their possible contribution to link problems.

These displays are in a fixed format, with names of the quantities arrayed in a column, with the information to be presented, if any, displayed to the left of the label. (Figure 3-66.)

In the alarm section, the designation of the particular redundant equipment holding an alarm is displayed; if nonredundant, an asterisk is entered. If both units of a redundant pair are alarmed, the designation of both is entered, that is, "AB." The term INVLD adjacent to FER, DERIVED BER and BER CORRELATION DIFF indicate an invalid measurement due to loss of signal.

Units of measure used for the numeric entries are:

RSL MARGIN	- dB ± 1 dB
EYE MARGIN	- dB ± 1 dB
DERIVED BER	- Orders of magnitude expressed exponentially ± 1 order of magnitude (i.e., E-9 = 10^{-9})
BER CORRELATION DIFF	- Difference of DERIVED BER-T1-4000 FER expressed exponentially (i.e., E - 1.2 = $10^{-1.2}$)
EYE BURST, FER	- Count (an integer power of 2 where the Count integer is rounded down to the next power of 2)

The status section indicators are handled the same way, except that obviously one, and only one, equipment will be in service at any one time.

The parameter section indicators which are displayed are measured on the in-service equipment only. The meaning of the parameters is explained in Volume II, Paragraph 3.4.5.2 and 3.4.5.3.

Page 2 provides alarm and parameter information for the T1WB1 and CY-104 equipment as shown in Figure 3-68.

LINK STATUS NO. 0219 STOCKSBERG - STUTTGART

	STB		SGT	
	T1-4000	RADIO	RADIO	T1-4000
ALARMS	SW MAJOR	TX	TX	SW MAJOR
	SW MINOR	RX	RX	SW MINOR
	MAJOR			MAJOR
STATUS	A TX IN SVC	A TX IN SVC	A TX IN SVC	A TX IN SVC
	A RX IN SVC	A RX IN SVC	A RX IN SVC	A RX IN SVC
	MAINTENANCE	MAINTENANCE	MAINTENANCE	MAINTENANCE
PARAMETERS	E-7 FER	30 RSL MARGIN	32 RSL MARGIN	E-7 FER
	REFRAME	30 EYE MARGIN	32 EYE MARGIN	REFRAME
		+2 EYE AMPL	+3 EYE AMPL	
		EYE BURST	EYE BURST	
		RX SQUELCH	RX SQUELCH	
		E-9 DERIVED BER	E-8 DERIVED BER	
	E-1.2BER CORRELATION DIFF		E-0.8BER CORRELATION DIFF	

FIGURE 3-66. LINK STATUS OUTPUT (NO ALARMS, NORMAL SERVICE) (PAGE 1)

LINK STATUS NO. 0219 STOCKSBERG - STUTTGART

	STB T1-4000	STB RADIO	SGT RADIO	SGT T1-4000
ALARMS	* SW MAJOR	TX	TX	* SW MAJOR
	* SW MINOR	AB RX	RX	* SW MINOR
	AB MAJOR			A MAJOR
STATUS	A TX IN SVC	A TX IN SVC	A TX IN SVC	A TX IN SVC
	A RX IN SVC	A RX IN SVC	A RX IN SVC	A RX IN SVC
	MAINTENANCE	MAINTENANCE	MAINTENANCE	MAINTENANCE
PARAMETERS	INVLD FER	0 RSL MARGIN	32 RSL MARGIN	E-7 FER
	AB REFRAME	0 EYE MARGIN	32 EYE MARGIN	B REFRAME
		+6 EYE AMPL	+3 EYE AMPL	
		EYE BURST	EYE BURST	
		* RX SQUELCH	RX SQUELCH	
		INVLD DERIVED BER	E-8 DERIVED BER	
	INVLD BER CORRELATION DIFF		E-0.8 BER CORRELATION DIFF	

FIGURE 3-67. LINK STATUS OUTPUT (R7A, R7B, NO RX PILOT) (PAGE 1)

LINK STATUS NO. 0219 STOCKSBERG - STUTTGART

	STB		SGT	
	CY-104	T1WB1	T1WB1	CY-104
ALARMS	SERVICE	OFFICE	OFFICE	SERVICE
	REMOTE			REMOTE
STATUS	MAINTENANCE	MAINTENANCE	MAINTENANCE	MAINTENANCE
PARAMETERS	CHNL AV	E-7 FER	E-7 FER	CHNL AV
	CHNL SN	REFRAME	REFRAME	CHNL SN
SITE ALARMS	BATTERY CHG		BATTERY CHG	
	INVERTER		INVERTER	
	WG PRESSURE		WG PRESSURE	
	WG HUMIDITY		WG HUMIDITY	
	AC POWER		AC POWER	
	BATTERY		BATTERY	

FIGURE 3-68. LINK STATUS DISPLAY (NO ALARMS NORMAL SERVICE) (PAGE 2)

3.4.5 Link Performance Assessment Outputs

3.4.5.1 Purpose and Organization

The purpose of the Performance Assessment Outputs is to organize link performance data, including statistics on past history, in an organized manner which allows detection of degradation, and inferences drawn about its sources.

They are organized in three pages for each link: a radio page, a T1-4000/radio interaction page, and a page for lower level (T1WB1 or CY-104) links.

In performance assessment, as opposed to fault isolation, comparison of performance on reciprocal paths, and comparison of performance of redundant units, is a subtle and powerful means of detecting degradation. Therefore, the organization of the displays in a format allowing ready comparison of performance rather than the complete data on a direction of transmission on each page is considered highly desirable.

3.4.5.2 Radio Page (Figure 3-69)

On the radio page are displayed the following parameters: RSL margin, eye margin, RSL unavailability, eye unavailability, and eye burst rates.

RSL margin is the difference between the RSL inferred from the measured value of AGC, and the RSL corresponding to PCM threshold. AGC is measured by the MAC, through the analog-scanners. The AGC is nominally proportional to the logarithm of the received power; however, an interpolation module is available if experience shows that the linearity is inadequate.

Eye margin is the fade margin available to PCM threshold, inferred from the eye dispersion alone, and compensating for high signal-level system distortion. This subject is covered in Appendix A.

The outputs from the eye pattern monitor are discussed in Paragraph 3.2.2. Figure 3-20, therein, shows the quantities which the monitor supplies to the CPU.

SGT-VHN RADIO LINK

		LAST SCAN	LAST HR MEAN	LAST 24 HR MEAN	LAST 24 HR DEV	LAST 30 DAYS MEAN	LAST 30 DAYS DEV	LAST 30 MO MEAN	LAST 30 MO DEV	UNITS
SGT	RSL Margin									dB
	Eye Margin									dB
A	RSL Unavailable									percent
	Eye Unavailable									percent
	Eye Burst Rate									/sec
SGT	RSL Margin									dB
	Eye Margin									dB
B	RSL Unavailable									percent
	Eye Unavailable									percent
	Eye Burst Rate									/sec
Joint	RSL Unavailable									percent
	Eye Unavailable									percent
VHN	RSL Margin									dB
	Eye Margin									dB
A	RSL Unavailable									percent
	Eye Unavailable									percent
	Eye Burst Rate									/sec
VHN	RSL Margin									dB
	Eye Margin									dB
B	RSL Unavailable									percent
	Eye Unavailable									percent
	Eye Burst Rate									/sec
Joint	RSL Unavailable									percent
	Eye Unavailable									percent

FIGURE 3-69. LINK PERFORMANCE ASSESSMENT RADIO PAGE

The approach to determination of eye margin is through use of stored characteristic curves. During system calibration, the offset voltage (b_1 in Figure 3-20) is determined as a function of signal power above PCM threshold. Points on this curve are stored in the PATE. In operation, measured values of offset voltage are used to derive, from the stored curves, an interpolated value of margin, which is the system output. The development of the theoretical technique from which this measurement is developed is discussed in Appendix A.

RSL unavailability is the ratio of the number of scans that the RSL was measured below a reference level to the total number of scans. The reference level is operator-programmable. RSL unavailability provides a measure of RF path performance.

Eye unavailability is analogous to RSL unavailability, and is the ratio of the number of scans in which the projected error rate exceeded a reference threshold to the total number of scans. The reference threshold is operator programmable and normally would be that value of reference threshold at which the projected error rate was equal to 10^{-7}. Eye unavailability provides a measure of the time the T1-4000 transmitter to T1-4000 receiver BER exceeds the acceptable programmed value of 10^{-7}, for example.

Both of the above unavailabilities are determined through subtraction of the references from the measured value in the PATE, and testing to see if the result is negative. The obvious thresholds are the "PCM thresholds," but may be changed in software if required.

Eye bursts are groupings of noise, observed in the baseband monitor, which significantly exceed the counts to be expected from system additive noise alone. The baseband monitor senses these and generates an output voltage related to the number of excess eye pattern excursions over that which would be expected with the normal residual system noise and intersymbol interference plus additive Gaussian noise. The display is in terms of the ratio of observed rate of excursions over the threshold to the expected number, expressed logarithmically in decibels.

The system unavailabilities are estimates of the unavailability of the diversity system obtained by multiplying the individual "A" and "B" unavailabilities by each other. This is a slightly optimistic estimation, in that statistical independence of the two receivers is assumed. This conditon is approached, but not attained.

3.4.5.3 Link Performance Assessment-Multiplex Page (Figure 3-70)

The multiplex page is an output to show the information derived from the T1-4000 multiplex itself, and the extent to which that information is correlated to anomalies observed from the radio set.

Since the standby T1-4000 receiver is not operating upon mission signals, information is collected only upon the equipment in service, passing operational traffic.

BER is the value of the T1-4000 BER estimated to have existed during the interval of observation by extrapolation of the observed framing bit errors. It is measured by the event counter in the digital scanner card; converted to an analog voltage proportional to the logarithm of the BER, and transferred to the PATE by the MAC in the normal scan.

For display and statistical calculation, the measured BER is compared to the BER availability threshold value. This availability threshold is operator programmable. If the BER is greater than the BER threshold, the scan is classified as a scan of BER unavailability. In this case, the BER measured is not averaged into the BER statistics although the measured BER is displayed.

BER unavailability is a measure of the number of scans during which the number of errors observed exceeded the number deemed acceptable for link performance. This can be set at the PATE by the operator as an operating threshold.

Control reframes (CRfrm) simply indicate whether or not one or more control reframes occurred during the interval between scans. Whenever a control reframe occurs, the event latch in the modified scanner card (EPUT) latches, and remains latched until scanned. The statistics thus are indicative of the percentages of scans containing one or more control reframes. Scans containing control reframes and low average error rate are indicative of periods of high impulse or burst noise. Conversely, scans containing high overall error rate and control reframes are scans corresponding to high overall error rate due to high Gaussian noise.

CRfrm/Squelch indicates whether or not both receiver squelch alarms were simultaneously "on" during a scan in which a control reframe was observed. It thus indicates that diversity loss of signal is a probable cause of reframe.

SGT-VHN LINK T1-4000 PERFORMANCE ASSESSMENT

		Last Scan	Last Hr Mean	Last 24 Hrs Mean	Last 24 Hrs Dev	Last 30 Days Mean	Last 30 Days Dev	Last 30 Mo Mean	Last 30 Mo Dev	Units
SGT A	BER									
	BER Unavailable									percent
	CTRL Rfrm									/day
	CRfrm/Squelch									/day
	CRfrm/Burst									/day
SGT B	BER									
	BER Unavailable									percent
	CTRL Rfrm									/day
	CRfrm/Squelch									/day
	CRfrm/Burst									/day
VHN A	BER									
	BER Unavailable									percent
	CTRL Rfrm									/day
	CRfrm/Squelch									/day
	CRfrm/Burst									/day
VHN B	BER									
	BER Unavailable									percent
	CTRL Rfrm									/day
	CRfrm/Squelch									/day
	CRfrm/Burst									/day

FIGURE 3-70. LINK PERFORMANCE ASSESSMENT DISPLAY (MULTIPLEX PAGE)

CRfrm/Bursts functions in a manner analogous to CRfrm/Squelch. If the observed signal burst rate exceeds a programmable threshold an alarm condition exists. The output thus indicates that a burst and a reframe were observed during the same scan. This indicates that the reframe was due to a noise burst rather than due to high residual noise.

3.4.5.4 The 1.544 Mb/s Page (Figure 3-71)

The 1.544 Mbps page, since it covers di-groups which may be associated with many radio links, displays only the error rate and reframe indications. These have the same meaning as on the T1-4000 display.

3.4.5.5 CY-104 and VF Displays

Individual displays are not devoted to the CY-104 and VF parameters since the pertinent parameters for these units are included on the Link Status Display.

3.4.5.6 Statistical Computations

a. Expected Nature of Variability. In considering the statistical processing of performance assessment parameters, it is important to recognize that, a priori, the nature of the probability distributions can only be roughly guessed. It is, therefore, not only undesirable, but possibly quite misleading to develop detailed methods of statistical analysis, based upon assumptions about the types of probability distributions expected.

Statistics are computed on parameters with three different expected general behavior.

RSL margin and Eye margin can be expected to show an approximately Gaussian distribution about their mean, within limits since these represent the differences between a normally distributed random variable (RSL and Eye scatter) and a constant. These differences, therefore, represent normally distributed random variables.

BER is a truncated probability distribution, since intervals with readings above the BER availability threshold as discussed in Section 3.4.5.3, are not averaged into BER, but counted as unavailable. The distribution of BER values, therefore, appears normal with the exception that the tail of the distribution function which corresponds to error rates in excess of the threshold value is absent.

SGT-VHN 1.544 Mbps PERFORMANCE ASSESSMENT T1WB1

		Last Scan	Last Hour	Day to Now	Previous Day Mean	Previous Day Dev	Previous Mo Mean	Previous Mo Dev	30 Month Mean	30 Month Dev
SGT No. 3	BER									
	Reframe									
VHN No. 4	BER									
	Reframe									

FIGURE 3-71. 1.544 Mbps LINK ASSESSMENT PAGE

The other parameters; RSL unavailability, Eye unavailability; BER unavailability; CRfrm, CRfrm/squelch correlations, and CRfrm/burst correlations, all indicate whether or not one or more events occurred within the period of a scan (of about five minutes). For a single scan their value is "yes" or "no" (1 or Ø).

b. Meaning of Statistical Outputs. In the interest of not presuming too much about probability distributions, and of minimizing the computational load, a standard method of calculating statistical outputs is used. The method used to calculate the various statistical parameters is diagrammed in Figure 3-72.

The "last scan" column shows the last measured value.

The "last hour" column presents the mean value of all measurements made within the past hour.

The "last 24 hour" column displays the mean and deviation of 24 hourly means, up to the past even hour.

The "last 30 day" column contains the mean and deviation of daily means of hourly means of the 30 days ending at 0000 of the current day.

"Last 30 months" is the mean and deviation of monthly means of daily means of hourly means of the 30 months immediately preceding the current month.

The intervals over which statistics are calculated will, in general, overlap. For an illustration, consider a performance assessment output requested at 0612 on 23 October 1984. The time periods covered by the various outputs are:

Last scan	last scan
Last hour	0512-0612 (10/23/84)
Last 24 hours	0600 (10/22/84) to 0600 (10/23/84)
Last 30 days	0000 (9/23/84) to 0000 (10/23/84)
Last 30 months	0000 (4/1/82) to 0000 (10/1/84)

3.4.6 Site Parameter Display (Figure 3-72)

3.4.6.1 Purpose and Organization

The site parameter display is designed to provide information on quantities which are interpretable directly from numbers received from the MAC. Examples are power supply voltages, and analog equipment parameters, such as receiver frequency offset voltage.

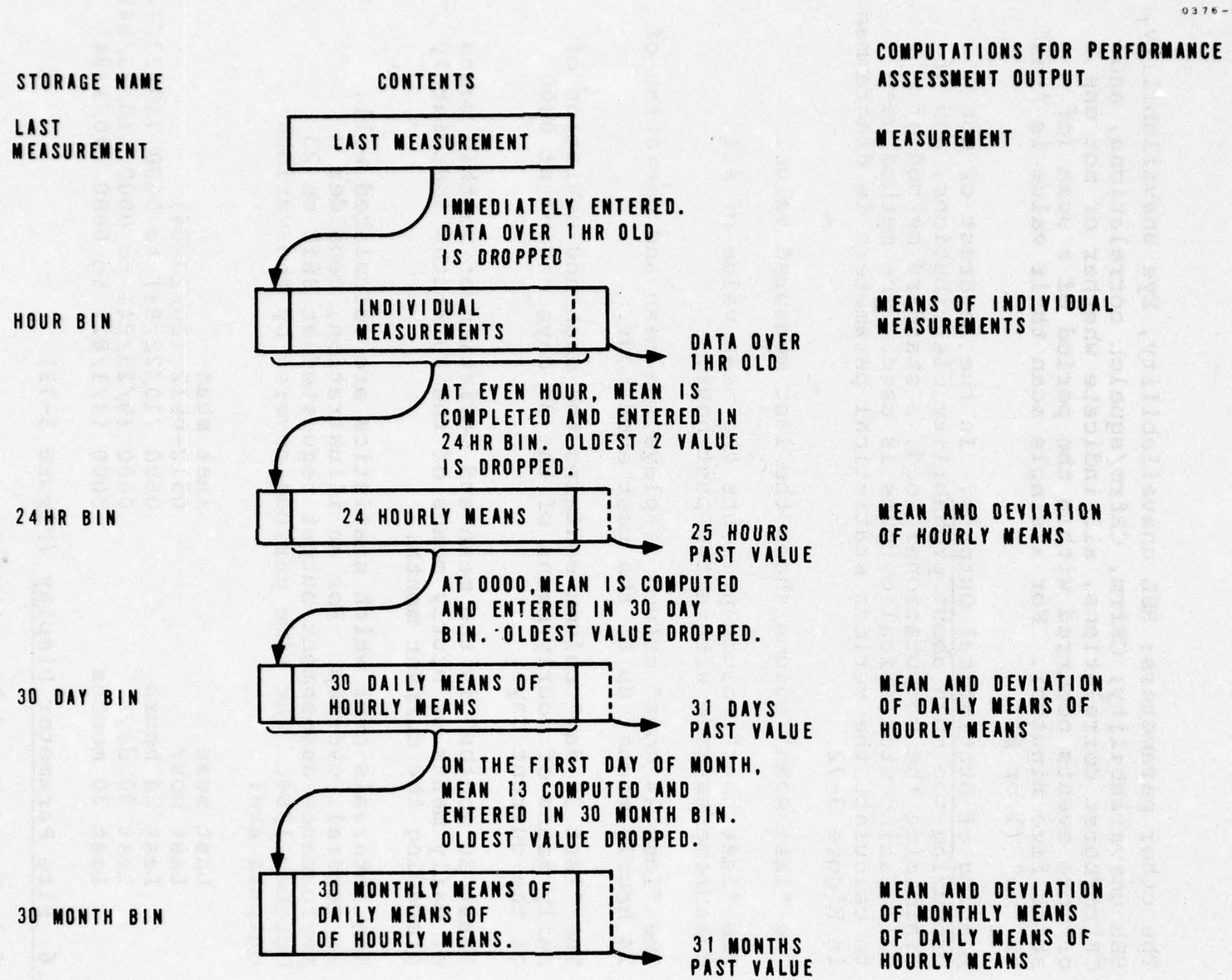

FIGURE 3-72. FUNCTIONAL CALCULATION OF STATISTICAL PARAMETERS

The display is best understood by reference to Figure 3-73.

The parameter name is at the left. Next is the nominal, center green, parameter value. The next column represents the measured difference observed at the last reading.

The next two columns represent the amount the parameter can vary below and above its nominal value and remain in the "green" range.

The last three columns relate to the statistics of the parameter; they provide the mean and standard deviation of all measurements made since the initialization date, which is shown in the last column.

SITE PARAMETERS STUTTGART

PARAMETER NAME	NOMINAL VALUE	MEASURED DIFFERENCE	ALARM DIFFERENCE -	ALARM DIFFERENCE +	MEAN	DEV	INITIALIZED DATE
FRC-162 A MAIN PWR	20.0	-0.8	0.5	1.0	20.2	0.20	12/6/82

FIGURE 3-73. SITE PARAMETER DISPLAY

Section 4

CONCLUSIONS

The ATEC Applicability/Adaptation Study concludes that the existing ATEC system and equipment, augmented by minor hardware and software adaptations, satisfy the monitoring system requirements of the FKV digital transmission system.

The recommended hardware adaptations provide for an adaptation to the baseband monitor in order to measure eye pattern parameters at the radio baseband interface, and an adaptation to the analog scanner in order to count and/or latch transient system and equipment events, e.g., multiplexer frame errors, reframes and radio squelch. Error control for alarm scanner telemetry, while recommended, is not included since it addresses a problem independent of the transmission system in use.

The recommended software adaptations for the PATE will permit the following functions to be provided:

a. Operator interaction to initiate nodal control monitoring and to permit operator access to data base parameters and thresholds which affect monitoring system performance.

b. Existing single line controller interrupt routines to handle MAC and MAD inputs and outputs.

c. Software modules to provide for nodal control monitoring and scanning of the FKV system.

d. Software modules to process the monitor point data and to drive the CRT displays and printer.

The ATEC applicability study has illustrated the ability of the ATEC system and equipments, through enhancement of inherent, latent capabilities, to satisfy the PA/FI/TA requirements of the FKV digital transmission system. The resulting monitoring system will provide the same level of PA/FI/TA in the FKV digital transmission system as is currently being provided by the ATEC monitoring system in FDM transmission systems. This commonality of monitoring system and equipments ensures the cost effective application of ATEC to the DCA PA/FI/TA requirements during the transition from FDM to PCM/TDM transmission systems.

Appendix A

DEGRADATION MONITORING OF A DIGITAL TRANSMISSION SYSTEM

A.1 INADEQUACY OF OUTPUT ERROR COUNTING FOR DEGRADATION MEASURING

Digital communication links are intentionally designed to have as large a tolerance to noise and other signal degradations as practicable. A system can have such a large built-in tolerance that it will still run error free even with one or more elements severely degraded. A primary objective of performance monitoring is to detect such degradations so that they may be corrected before the digital link begins to make errors. It is obvious that the desired information for meeting this objective cannot be obtained by examining the digital output because the objective is to detect degradations while this output is still error free. Presumptive tests which remove digital links from service long enough to run test sequences through them for measuring error rate, as well as error detecting and correcting codes all have valid applications in performance monitoring; however, they are not adequate for measuring performance margin under error free conditions because they give no indication of degradations until they have become bad enough to cause errors in the received data. An ideal degradation monitoring technique should be capable of detecting degradations before they become large enough to cause errors in the received data.

The ability to detect signal degradations before they become large enough to cause errors in the received messages is vitally important for both analog and digital channels; however, the channel users ability to detect gradually increasing degradations and anticipate loss of the channel is far better for analog voice channels than digital communication links. In analog communication links, such as voice channels, the channel induced noise and distortion are delivered to the user along with the desired signal hence these degradations can be detected by the user. These degradations are detectable by the user at power levels several decades lower than the level at which they make the channel unusable by lowering the intelligibility index of the voice signal below an acceptable level. Thus in analog communication channels there is typically a large margin between the level at which noise and distortion is detectable and that at which it becomes intolerable. Furthermore, the user of a voice channel can readily estimate the degree of channel degradation by a qualitative estimate of signal intelligibility. The user of a digital channel is presented with a very different situation because each digital receiver in the communication chain reshapes the digital pulses so that the symptoms of channel noise and distortion are removed before the signal is forwarded.

The primary intended effect of pulse reshaping between the links of the digital communication chain is to reduce the message error rate by stripping off noise and distortion at each link interface so that these

individual link induced distortions are not allowed to accumulate as they would in an analog system. Thus, even if the sum of the noises and distortions for the total number of links is so large as to produce an intolerable error rate for an end to end digital system using no intermediate pulse reshaping, it is often possible to reduce the end to end error rate to approximately zero by stripping off the noise and distortion and regenerating the digital signal at selected locations in the chain. As long as the cumulative degradation in each individual link is kept below the critical level for that link, each link will run error free, and hence, the end to end channel will run error free. On the other hand, if the degradation in one, several, or all of these links is just slightly below the critical level at which it begins to produce errors there will be no indication of this impending problem in the error-free data stream delivered to the user. Thus, the pulse reshaping in digital systems is advantageous in that it can help reduce the error rate of the system; however, it removes symptoms of channel degradation from the output data signal. Since the digital output signal gives no indication of degradation until errors actually occur in the output, the user who has nothing but the receiver digital signal to work with has no means of estimating how close the channel degradations are to the critical levels until after one or more of those levels has been exceeded.

The inability of the user to detect gradual channel degradations until they are already large enough to be producing errors in the received digital data stream would be less objectionable if there were a greater separation between the degradation level at which the error rate becomes just barely measurable and that at which it becomes intolerable. Assuming that the degrading factor is additive uncorrelated Gaussian noise then the amplitude of the noise will be distributed in accordance with the cumulative Normal probability function plotted Figure A-1. Observe that the probability, $P(z>t)$, of the normally distributed noise amplitude, z, exceeding an arbitrary threshold, t, decreases so rapidly with increasing t that even when using a seven decade semilog scale, the probability function crosses the plot vertically more than seven times (indicating more than 49 decades) as the amplitude of t is changed less than 24 db (1.2 decades). As a consequence of this extremely rapid change of $P(z>t)$ with respect to t, the bit error rate of a digital receiver can change very rapidly with respect to small changes in the amplitude of the additive Gaussian noise. For an ordinary PAM (pulse amplitude modulated) signalling it can be shown that the BER (baud error rate; that is, probability of receiving one or more bits incorrectly in one baud) for additive uncorrelated Gaussian noise can be computed from the following relations.

$$BER = 2\left(1 - \frac{1}{L}\right) P\left(z > \sqrt{\frac{3}{(L^2 - 1)} \frac{S^2}{N^2}}\right)$$

where

$L \equiv$ number of levels per baud

$z \equiv$ normally distributed random variable with mean = 0 and variance = 1.

$S^2 \equiv$ signal power at decision circuit.

$N^2 \equiv$ noise power at decision circuit.

$P(z>\cdots) \equiv$ the probability plotted in Figure A-1.

For the most common types of partial response signaling (Class I with n=2 and Class IV with n=3 per Reference 9) the BER can be computed using the similar relationship shown below.

$$\text{BER}^* = 2\left(1 - \frac{1}{M^2}\right) P\left(z > \sqrt{\frac{3}{2(M^2-1)}\,\frac{S^2}{N^2}}\right)$$

where

$$M \equiv \frac{L+1}{2}$$

*The reason that the above equation for BER requires a 0.91210 db higher signal to noise ratio than that given on page 89 of Reference 10 is that Lucky, Salz & Weldon's equation was derived for measuring SNR at the receiver input with half of the partial response shaping in the transmitter and half in the receiver whereas the above equation is for SNR measured at the decision circuit regardless of how the partial response filtering is partitioned.

To clearly illustrate how the BER can change from a value essentially equal to zero to a value so large as to be intolerable for a relatively small change in signal to noise ratio, the BER for a three level 12.5 meg bit/sec partial response signal has been computed and the results are presented in Table A-1.

TABLE A-1

Errors/Time	BER	(Signal/Noise) db
10,000 errors/second	8×10^{-4}	13.31
100 errors/second	8×10^{-6}	15.89
1 error/second	8×10^{-8}	17.52
1 error/minute	1.33×10^{-9}	18.60
1 error/hour	2.22×10^{-11}	19.46
1 error/day	9.26×10^{-13}	20.04
1 error/year	2.54×10^{-15}	20.94
1 error/century	2.54×10^{-17}	21.53

1275-501

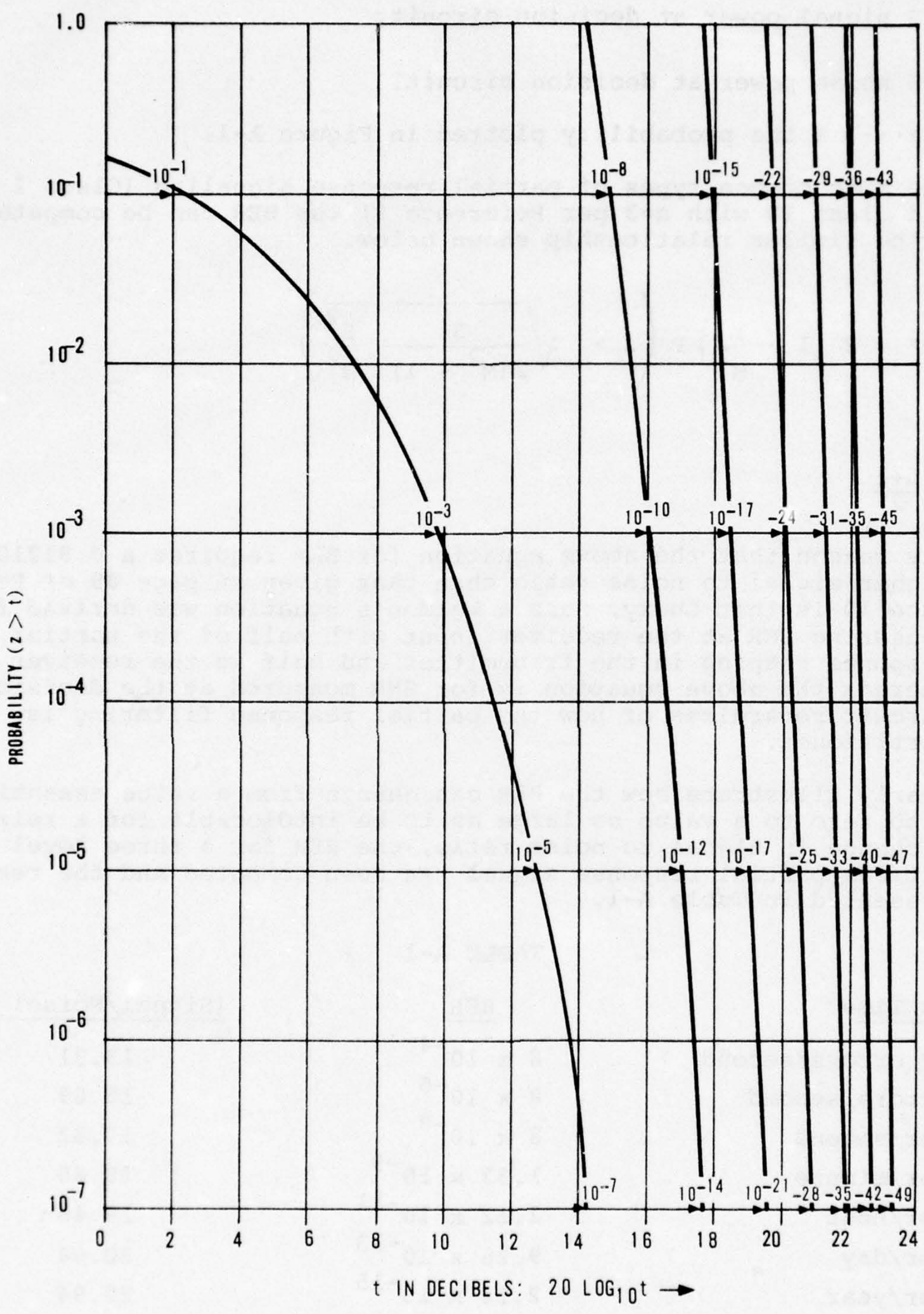

FIGURE A-1. PROBABILITY THAT $z > t$ GIVEN THAT z IS NORMALLY DISTRIBUTED WITH MEAN = 0 AND VARIANCE = 1

Table A-1 shows that the difference in signal to noise ratio, SNR, for 100 errors per second and for one error per century is only 5.64 db. For a reasonably accurate performance measurement it is necessary to observe a significant number of errors because the standard deviation of the number of errors measured per sample is essentially equal to the square root of the average number of errors measured per sample. For example; if the average number of errors per sample is 100 then the standard deviation is computed as $\sqrt{100} = 10$ which means that the BER is being measured with error of about 10 percent, one sigma. For measurement periods of one hour the computed error rate will be based on error observations which on the average are half an hour old at the time the computation is made. Also, for one hour long measurements, the percentage error in the measurement will increase rapidly as the error rate drops below 1 error per minute. The signal to noise ratio producing one error per minute is only 2.71 db lower than that producing 100 errors per second which is not considered to be a very good margin for a performance degradation detector which is intended to predict rather than confirm system failure. If a larger error sample is taken to increase the margin (measured in db) of the monitor, the measurement will take longer causing an even longer delay in the monitoring process. The conclusion is that counting errors in the output data stream as a means of predicting the failure of a digital system suffering gradual degradation leaves a lot to be desired. Fortunately, more powerful degradation detection techniques are available as will be described in the next section.

A.2 EYE PATTERN MEASUREMENTS FOR DEGRADATION MONITORING

The eye pattern shown in Figure A-2 was obtained by taking a time exposure of an oscilloscope presentation of the voltage at the input to the decision circuit of a VICOM T1-4000 multiplexer. At the sampling times the voltage ideally would be exactly at one of three distinct levels; hence, this is called a three-level eye. Ideally, the decision circuit will sample the eye pattern voltage at each of the sampling times and decide whether an upper, center, or lower level signal was intended to be received at that sampling time. Additive noise will cause the voltages to deviate from their ideal values thus widening the lines on the oscilloscope picture in the vertical direction. As the noise increases, the images corresponding to the upper, middle, and lower levels widen. When the images of the levels become so wide that there is no longer a clear separation between levels, the decision circuit will begin to misinterpret the intended message which causes errors. The spaces separating the images of the various levels at the sampling points are called the "eyes". When signal degradations become so bad that these spaces shrink to zero, the "eyes" are said to "close". When the eyes are closed, the receiver will be making errors.

The size of the eye openings relative to the distances between the centers of adjacent levels expressed as a "percentage of eye opening" has long been used as a figure of merit for performance measurement and it is a good one if its limitations are understood. First, if the decision voltage levels of the decision circuit are not located

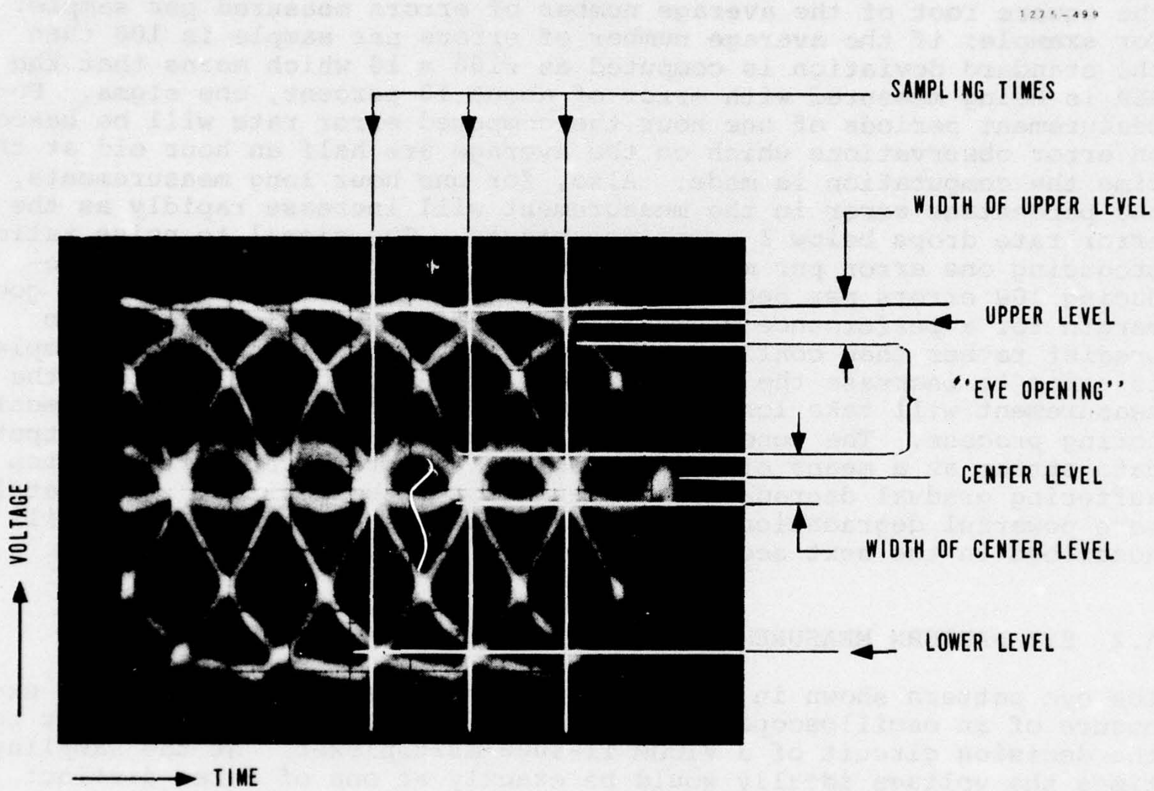

FIGURE A-2. EYE PATTERN FOR THREE LEVEL PARTIAL RESPONSE SIGNAL

in the center of the eye vertically and, second, if the sampling times are not centered in the eyes horizontally then the receiver will begin to make errors before the eye is totally closed. Third, since the noise typically has a Gaussian amplitude distribution the width of the levels (and hence the percentage of eye opening) is not sharply defined because the level width image on the oscilloscope can be varied from about ±1 sigma depending upon the intensity setting of the oscilloscope and the length of the time exposure for averaging time).

These three limitations may be overcome by proper system design as will be discussed in the following paragraphs. The techniques to be discussed apply to eye patterns with any number of levels; however, the discussions will be concentrated primarily on the three level case because the two level case is too simple to display generality while examples involving more than three levels would make the explanation more cumbersome without adding any significant degree of insight.

Conceptually, what the eye pattern monitor should do is to measure the probability density function of the signal perturbations from the ideal levels so that the desired error rates and performance margins can be computed. In actual practice, point by point determination of the probability density function is too expensive. A practical alternative is to assume that the distribution of the perturbation amplitudes is Gaussian and make some measurement from which the rms amplitude of the distribution may be inferred. Since there are several common conditions such as additive tones, highly correlated intersymbol interference, and impulse noise for which the distribution of the perturbations deviates significantly from Gaussian it is desirable to augment the first amplitude measurement with a second measurement which can indicate either that the distribution is Gaussian or indicate the nature of its deviation from Gaussian.

To measure the signal perturbations from the nominal levels, it is first necessary to determine the exact amplitude of the nominal levels so that when we measure the distances from the nominal reference levels to the observed signals we will be measuring signal perturbations only-- not perturbations plus or minus the error in measuring the nominals. Automatic gain control systems based on measurement of signals biased by noise (References 4, 6, and 8) have been used for this purpose but the nominal level of the signal which they control will necessarily change as the amount of noise changes. Another example of how the signal level may become dependent upon noise amplitude is the VICOM T1-4000 multiplexer which uses a peak clipping circuit for its amplitude sensing signal so that the larger the noise is the smaller the signal will be. The system concept proposed here for measuring the nominal levels in the eye pattern degradation monitor is to adjust the reference level of a comparator with a feedback loop such that 50 percent of the samples associated with that level fall above that level and the other 50 percent fall below that level. The hardware needed to implement this concept is reasonably simple.

Conceptually, it would be possible to subtract the nominal levels from the observed levels to obtain the perturbation amplitudes, compute the rms value of these amplitudes, and assume that the perturbations are

normally distributed with a mean of zero and a standard deviation equal to the measured rms value. In actual practice it would be difficult to mechanize the above system for a 12.5 megabaud/sec receiver. Also it would be desirable to make some additional measurement (such as rectified average versus rms) to test the distribution for deviation from Gaussian. For building a device which will measure eye quality at 12.5 megabaud/sec a system which uses one or more additional comparators offset from the nominal levels to sense the amount of signal perturbation from nominal seems to be a practical compromise between complexity and performance.

The offset threshold monitors described in References 5 and 6 use comparators with offset thresholds as described above to measure signal quality and, therefore, they have been carefully analyzed to determine their capabilities and limitations. One of the biggest disadvantages of this mechanization from an operational viewpoint is that its quality output signal has no absolute scale such that a specific output voltage would have a specific meaning. The calibration of the device is accomplished after it is attached to the specific multiplexer which it is to monitor. In accordance with the calibration procedure, all monitors on all multiplexers are adjusted to indicate a signal quality of 0.10 volt at the end of calibration regardless of individual variations in the operating conditions of the various multiplexers at time of calibration. To take an absurd example, if a signal quality monitor indicated a problem with a multiplexer, the first troubleshooting step might be to check the calibration of the degradation monitor by repeating the calibration procedure in which case the symptom of trouble would automatically disappear regardless of the condition of the multiplexer. Assuming that a calibration technique could be developed for circumventing the above problem, the existing offset threshold monitor is still not recommended because it uses a fixed (adjusted by a potentiometer during calibration) offset from the nominal reference level as a reference voltage for the comparator used to measure "pseudo error rate". With the aid of Figure A-3, the measured "pseudo error rate" may be defined as equal to the number of samples observed between upper data decision threshold at +d volts and the upper offset threshold at + (2d-b) volts plus the number of samples observed between corresponding pair of lower thresholds -d, and -(2d-b) divided by the number of sampling periods over which the count was made. When a fixed threshold offset, b, is used, "pseudo error rate" measurements suffer from the same rapid changes for small changes in signal to noise ratio as previously described for counting actual errors. If the offset voltage, b, is made too large, the pseudo error rate will be too small to make accurate measurements of low level degradations. If the offset voltage, b, is made too small the error rate will change rapidly for small degradations but tend to remain nearly constant at nearly 25 percent (assuming that the outer signaling levels are used 50 percent of the time) for large noise levels in the amplitude range of greatest interest where the system just begins to make actual errors. In either case, the error rate variation versus noise level is a highly nonlinear function which is not readily interpreted.

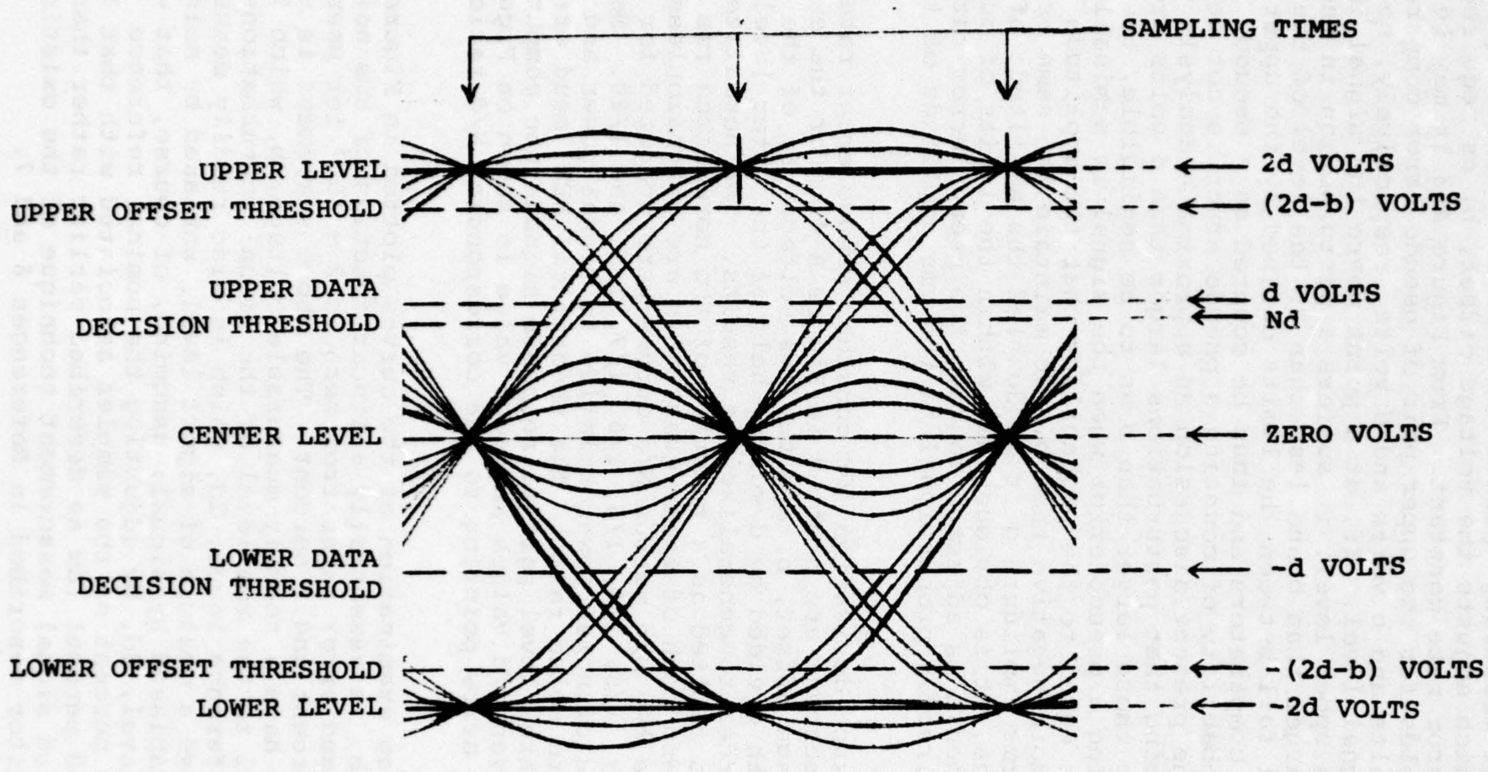

FIGURE A-3. DEFINITION OF LEVELS FOR OFFSET THRESHOLD MONITORING OF THREE LEVEL EYE

The recommended solution to the dilemma as to how large to make the voltage offset, b, for measuring "pseudo error rate" is to design a closed loop system which adjusts the voltage offset, b, as required to keep the pseudo error rate constant. From Figure A-3 it may be seen that the thresholds for the upper pair of pseudo error comparators at 2d-b and d volts and b volts and d volts, respectively, below the nominal upper signal level. If, at a point where the signal is supposed to be at its upper level, it suffers a perturbation in the negative direction larger than b and less than d, the level of the perturbed signal will fall between the limits defined by the upper pair of pseudo error comparators and thus be counted as a pseudo error. The exact probability of counting a pseudo error is not derived here but for the present discussion an approximate analysis will be meaningful. Assuming that perturbations larger than d volts are so rate compared with those larger than b as to be negligible, the probability of counting a pseudo error when the signal is nominally at the upper level is equal to the probability that the amplitude perturbation, ε, is more negative than b. To maintain the same pseudo error rate when the rms amplidute of ε is doubled the amplitude of b must be doubled. Thus, it is obvious that within the limits of our approximation that when b is adjusted to keep the pseudo error rate constant that b is directly proportional to the rms amplitude of the perturbations ε.

The results of the exact derivation for constant pseudo error rates of 10 percent and 1 percent are plotted in Figure A-4. For the exact derivation, the voltage offset, b, and the rms voltage, N, of the perturbations are both divided by d volts, half of the outer level signal voltage, in order to generalize the results. The normalized voltage offset b/d is plotted as a function of the normalized rms noise amplitude N/d and both of these quantities are dimensionless. The ordinates for the two b/d versus N/d curves were computed for the seven N/d values: 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, and 1/20. Notice that N/d is a measure of noise power relative to signal power and hence a measure of signal to noise ratio. The theoretical BER (baud error rate) for standard three level partial response signals was computed for each of these seven N/d values and each value is shown on Figure A-4 above a vertical arrow pointing to the corresponding N/d ratio for that BER.

As may be seen from an examination of the curves plotted in Figure A-4, the voltage offset, b, is essentially a linear function of rms noise level for receiver baud error rates from zero to 2×10^{-3} for pseudo error rates of 10 percent and 1 percent. The above statement is very significant. We now have a readily measurable voltage, b, which is linearly proportional to the rms level of the signal perturbations about the nominal reference level, 2d, which is also readily measurable. That is, we have a measure of signal level, unbiased by noise and of noise level unbiased by signal; assuming, of course, that we measure the signal level, 2d, by adjusting the nominal reference comparator to get 50 percent of the samples associated with that level high and the other 50 percent low as described earlier rather than using the noise biased signal measurement technique of the existing offset threshold monitor described in References 6 and 7.

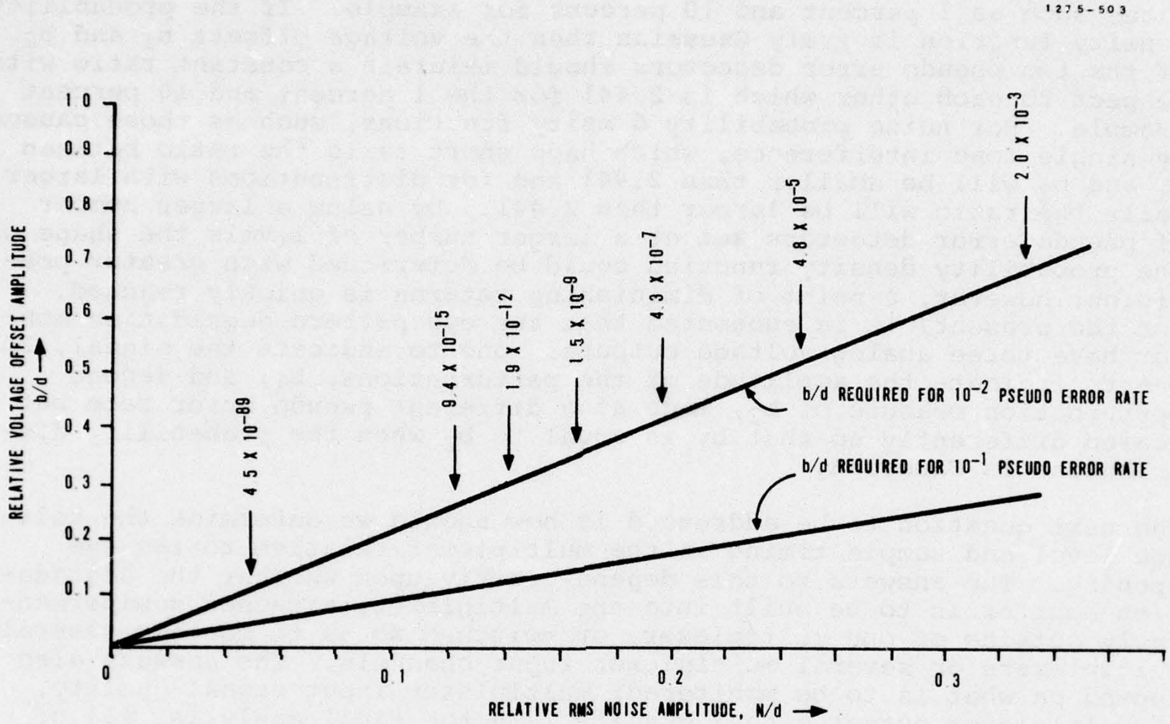

FIGURE A-4. VOLTAGE OFFSET AMPLITUDE VERSUS NOISE FOR CONSTANT PSEUDO ERROR RATE (THREE LEVEL)

We now have a measurement of the signal amplitude and the noise amplitude,-- what is still needed is a test to determine whether or not the probability density function of the noise fits the Gaussian probability distribution. This capability can be readily provided to two pseudo error detectors which are controlled to two different pseudo error rates such as 1 percent and 10 percent for example. If the probability density function is truly Gaussian then the voltage offsets b_1 and b_2 of the two pseudo error detectors should maintain a constant ratio with respect to each other which is 2.441 for the 1 percent and 10 percent example. For noise probability density functions, such as those caused by single tone interference, which have short tails the ratio between b_1 and b_2 will be smaller than 2.441 and for distributions with larger tails the ratio will be larger than 2.441. By using a larger number of pseudo error detectors set at a larger number of levels the shape of the probability density function could be determined with greater precision; however, a point of diminishing returns is quickly reached. For the present, it is suggested that the eye pattern degradation monitor have three analog voltage outputs: one to indicate the signal, 2d; one to indicate the amplitude of the perturbations, b_1; and second perturbation measure of b_2, made at a different pseudo error rate but scaled differently so that b_1 is equal to b_2 when the probability distribution is Gaussian.

The next question to be addressed is how should we determine the voltage level and sample timing in the multiplexer relative to the eye opening. The answers to this depend greatly upon whether the degradation monitor is to be built into the multiplexer, attached semipermanently outside of one multiplexer, or switched so as to monitor several multiplexers or several multiplexer input channels. The answers also depend on what is to be monitored; multiplexer input signal quality, or multiplexer output signal quality. In the final analysis, all of the above decisions should be based on maximizing the usefulness of the incremental monitoring capability purchased per incremental dollar spent. For monitoring a single multiplexer, the most cost effective solution seems to be to use the timing signals and baseband eye pattern from the multiplexer such as the existing offset threshold monitor does with the possible addition of test points for measuring the decision reference threshold voltages. In this case, certain failures in the multiplexer will be detectable by the eye pattern monitor.

On the other hand, if eye pattern monitoring is to be done in conjunction with several multiplexers, the most cost effective solution seems to be to build a single, standalone self-contained eye pattern monitor which performs all of the automatic gain control, signal spectrum shaping, and timing recovery functions which the associated multiplexers perform so that the monitor can be switched from one multiplexer input to another by a scanning selector. Thus, a single eye pattern monitor can sequentially monitor the input quality of the input signals for an indefinite number of multiplexers. In this case, failures in the multiplexers (other than dead shorts at the inputs, etc.) would not alter the output of the eye pattern monitor.

A.3 DERIVATION OF VOLTAGE OFFSET VERSUS NOISE FOR CONSTANT PSEUDO ERROR RATES

We now derive the relationship shown in Figure A-4 which indicates how the voltage offset b (normalized by dividing it by d) must be adjusted to keep the pseudo error rate constant as the rms noise level N (normalized by dividing it by b) changes. This relationship is derived for the three level partial response signal shown in Figure A-3. It is assumed that noise at the sample points is normally distributed with a mean equal to zero and a standard deviation equal to N.

It is further assumed that two pairs of comparators are used. One pair measures the number of samples between d and (2d-b) volts, the other measures the number of samples between -d and -(2d-b) volts. In actual practice the pseudo error rate measured by the upper pair of comparators may differ from that measured by the lower pair because the signal waveform may be distorted by clipping or saturation in such a manner that only one side is distorted. For this reason, it is considered necessary to use two sets of comparators so as to test both the top and bottom levels of the signal.

In the idealized case which we are considering here, the upper and lower comparator sets would both obtain the same average number of pseudo errors; hence, in this derivation, we shall derive the average rate for the top pair alone and then multiply by two to obtain the total pseudo error rate.

The magnitude of each received voltage sample is equal to its nominal intended magnitude +2d, 0, or -2d volts plus the magnitude of the signal perturbation, ε. In accordance with our previous assumption, ε must be a normally distributed random variable with mean equal to N. The probability of a particular sampled voltage amplitude falling between d and 2d-b volts depends upon whether the nominal intended level was 2d, is equal to the probability that ε is of the proper size to cause the sampled voltage to fall within the specified range.

$$P\ (\text{upper pair detects pseudo error} \mid \text{intended level} = 2d)$$

$$= P\ (d \le 2d+\varepsilon < 2d-b)$$

$$= P\ (-d \le \varepsilon < -b)$$

$$= P\ [-d/N \le \varepsilon/N < -b/N \mid \varepsilon/N \sim N(0,1)\ ]$$

$$= P\ [b/N < z \le d/N \mid z \sim N(0,1)\ ]$$

$$= Q(b/N) - Q\ (d/N)$$

where

$$Q\ (t) \triangleq P\ [z > t \mid z \sim N(0,\ 1)\ ]$$

$= P\ (z > t)$ given z is normally distributed with mean = 0 and variance = 1.

The conditional probability of the upper pair of comparators detecting a pseudo error given that the intended level was zero may be computed similarly.

P (upper pair detects pseudo error intended level = 0)

$= P\ (D < 0+\varepsilon \leq 2d-b)$

$= P\ [d/N < \varepsilon/N \leq (2d-b)/N \mid \varepsilon/N \sim N(0,\ 1)]$

$= Q(d/N) - Q(2d-b)/N$

Likewise,

P (upper pair detects pseudo error intended level = -2d)

$= P(d < -2d+\varepsilon \leq 2d-b)$

$= P(3d < \varepsilon \leq 4d-b)$

$= P\ [3d/N < \varepsilon/N \leq (4d-b)/N \mid \varepsilon/N \sim N(0,\ 1)]$

$= Q(3d/N) - Q(4d-b)/N$

For the three level partial response signal considered here the probability of level +2d, 0, or -2d being intended is 1/4, 1/2, or 1/4, respectively. Therefore, the probability of the upper pair of comparators detecting a pseudo error is as follows.

P (upper pair detects pseudo error)

$= 1/4\ \{Q(d/N) - Q(d/N)\}$

$= 1/2\ \{Q(d/N) - Q[(2d-b)/N]\}$

$= 1/4\ \{Q(3d-N) - Q[(4d-b/N]\}$

$= 1/4\ \{Q(d/N) + Q(d/N) - 2Q[(2d-b)/N] + Q(3d/N) - Q[(4d-b)/N]\}$

Given that both an upper pair (2d-b and d) and a lower pair (-2d+b and -d) of pseudo error comparators are to be used, and assuming that both pairs detect the same average number of errors, the total pseudo error error rate will be twice that derived above.

P (pseudo error)

$= 1/2\ \{Q(b/N) + Q(d/N) - 2Q[(2d-b)/N] + Q(3d/N) - Q[(4d-b)/N]\}$

Using the above equation we may solve explicitly for P (pseudo error) as a function of the two normalized variables b/N and d/N (or N/d if preferred). To obtain the points required to plot b/N as a function of N/d for a constant value of pseudo error, as shown in Figure A-4, it would be convenient to have an equation expressing b/N as an

explicit function of P (pseudo error) and N/d. Not having such an explicit relationship for b/N, the above equation was solved iteratively for each fixed value of N/d by adjusting b/N successively until the desired value of P (pseudo error) was obtained to the desired accuracy. The initial value of b/N for each series of iterations could be solved for explicitly using the following approximation which neglects the last three terms of the equation.

$$P\ (\text{pseudo error}) \approx 1/2 \quad Q(b/N) + Q(d/N)$$

$$Q(b/N) \approx 2\ P\ (\text{pseudo error}) - Q(d/N)$$

$$b/N \approx Q^{-1}\ [2\ P\ (\text{pseudo error}) - Q(d/N)]$$

For the points shown in Figure A-4 the above approximation is quite accurate.

For example, the approximation is poorest at N/d = 1/3 and P (pseudo error) = 0.01 at which point the approximation gives

$$b/N \approx Q^{-1}\ [0.02 - Q(3)] = 2.0829$$

After iterative solutions to find an improved value for b/N, we obtain b/N = 2.0805. Substituting b/N - 2.0805 and N/d = 3 into the precise equation for P (pseudo error), we obtain the following numerical solution.

P (pseudo error)

$$= 1/2\ \{Q(2.0805 + Q(3) - 2Q(3.9195 + Q(9) - Q(9.9195)\}$$

$$= 1/2\ \{0.0187398 + 0.0013500 - 0.0000888 + 1.15 \times (10)^{-19}$$

$$- 1.75\ (10)^{-23}\}$$

$$= 1/2\ (0.0200010) = 0.0100005$$

Notice that the fourth and fifth terms of the exact expression were truly negligible at this point and the effect of the third term was small only changing b/N from 2.0829 to 2.0805; that is, 0.1 percent.

It is significant to check the accuracy of the one term approximation for P (pseudo error) because the one term approximation produces a linear relationship between b and N which is convenient for interpreting the output of the degradation monitor.

$$P\ (\text{pseudo error}) \approx 1/2\ Q(b/N)$$

$$b/N \approx Q^{-1}\ [2\ P\ (\text{pseudo error})]$$

for

$$P\ (\text{pseudo error}) = 0.01,$$

$b \approx N\,Q^{-1}\,(0.02) = 2.0542\ N$

$b/d \approx 2.0542\ N/D$

The above equation defines the asymptote which the 0.01 pseudo error rate curve on Figure A-4 approaches as N/d approaches zero. Collecting results where P (pseudo error) = 0.01 and N/d = 1/3,

Using all five terms, $b/N \approx 1.0805$, exact

Using three terms, $b/N \approx 2.0805$, negligible error

Using two terms, $b/N \approx 2.0829$, 0.1 percent high

Using one term, $b/N \approx 2.0542$, 1.3 percent low.

Since the P (pseudo error) = 0.01, N/d = 1/3 point was selected as the point farthest away from the one term asymptotic approximation for all points computed in plotting Figure A-4, the one term approximation is adequate for most purposes over the range of values plotted. Using this approximation, the rms noise level is directly proportional to the measurable voltage with a known scale factor; hence, we have a means for determining the rms noise level.

The actual (not pseudo) baud error rate for the transmitted data may be conveniently computed from the following equations which are equivalent to those given earlier except that the rms signal power parameter, S, has been replaced with the closely related parameter, d, which as defined previously is equal to half of the voltage difference between adjacent levels.

For ordinary (that is, all levels equally probable) PAM signaling with L levels,

$$\begin{aligned} BER &= 2(1 - 1/L)\ P(E > d) \\ &= 2\ (1 - 1/L)\ P[E/N > d/N \mid d/N \sim N(0,1)] \\ &= 2(1 - 1/L)\ Q(d/N) \end{aligned}$$

Similarly, for the most common types of partial response signaling (Class I with n=2 and Class IV with n=3),

$$BER = 2(1 - 1/M^2)\ Q(d/N)$$

where

$M \equiv L+1/2$ as before.

Note that d and N are both measured by the proposed eye pattern monitor and that L is simply the number signaling levels; hence, the eye pattern monitor output signals are sufficient for computing the actual error rate assuming that the distribution of the perturbation is Gaussian.

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Appendix B

INFERRING DIGITAL ERRORS FROM ANALOG VF MEASUREMENTS

B-1 GENERAL

In a PCM system, carrying analog signals, errors in the digital stream will produce effects upon the reconstructed analog signal in the receiver. It is a superfically attractive method of monitoring the FKV network, since it contains a large number of PCM multiplex equipments, and analog VF channel test equipment is widely available and understood.

B-2 REVIEW OF PCM ENCODING AND DECODING

The analog input signal to the transmitter is bandpass filtered, to a band of 180 to 3400 Hz. It is sampled at a rate of 8000 samples per second.

The samples are compressed by an approximation to a logarithmic compression rule. The first approximation to logarithmic compression is the relationship

$$e_{out} = \operatorname{sgn}(v) \frac{\ln(1 + \mu|v|)}{\ln(1 + \mu)}$$

where v = input voltage; $-1 \leq v \leq +1$; and $\mu = 255$

To simplify mechanization, this relationship is further approximated by a sixteen segment compression curve. The segments themselves satisfy the logarithmic curve, but the subsegments represent equal voltage increments within the segment. Sixteen subsegments are used per segment.

The compressed signal is converted to a binary word which represents the next higher binary approximation to the signal. The relationship between input voltage and the encoded binary word is shown in Figure B-1.

The eight-bit binary word is organized as follows. The first bit represents the sign. The next three bits indicate the segment. The last four bits represent the subsegment.

These binary words are interleaved with those representing the other 23 channels and sent through the digital transmission system. At the receiver, the reverse process occurs. The individual channels are separated. The eight-bit word is decoded and converted to PAM samples. These samples are filtered, amplified, and become an analog signal at the output port.

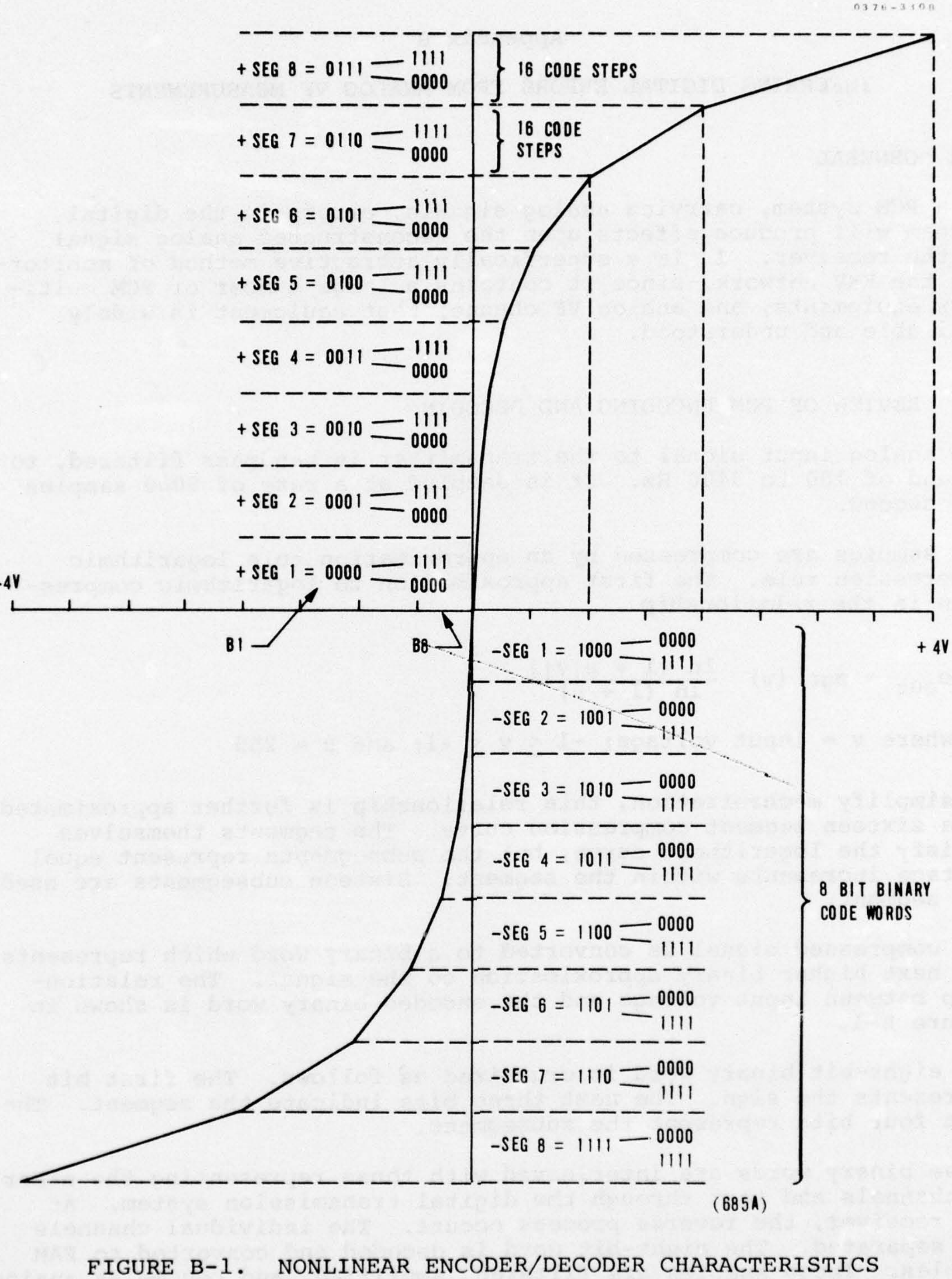

FIGURE B-1. NONLINEAR ENCODER/DECODER CHARACTERISTICS

B-3 SMALL SAMPLE SIZE PROBLEM

If the error process is assumed to be a statistically stationary Poisson process (which in general, it is not), the expected numbers of errors per unit time at various levels of the system can be calculated:

	Digital Baseband	T1-4000 Frame Bits	CY-104 Channels	CY-104 Frame Bits & Individual Channel Bit Positions
P(e)	Seconds Per Error	Seconds Per Error	Seconds Per Error	Seconds Per Error
10^{-7}	0.8	100	2.6 minutes	21 minutes
10^{-6}	0.08	10	15.6 seconds	2.1 minutes
10^{-5}	0.008	1.0	1.6	12.5 seconds
10^{-4}	0.0008	0.1	0.16	1.25

The performance assessment problem is the detection of error conditions residing between the rates listed above. Furthermore, in inferring digital errors from analog measurements, we are in the order of magnitude of the right-hand column above, as will be shown later.

The temporal response characteristics of measuring devices must be examined now. Analog measuring sets typically have time constants of tenths of seconds. The IQCS, uses 1.6 seconds worth of samples for power measurements and 320 milliseconds for frequency related measurements.

Thus, with these types of devices, the error problem is not that of reading a meter whose indication is relatable to errors. It is, rather, whether or not something happened when the observer (or system) was looking.

The observations above have been made under the assumption of statistical stationarity. While this may be valid for part of the error producing mechanisms, it is known to be invalid for two of the biggest contributors; reframes and radio fades.

B-4 EFFECTS OF ERRORS ON IDLE CHANNELS

If it is assumed that errors are introduced randomly into the digital stream between transmitter and receiver, it is equiprobable that any one bit is in error.

If the sign bit is in error, the output is of the correct amplitude but wrong polarity. If the other bits are in error, the wrong amplitude is transmitted.

The probability of one bit in error of the seven amplitude bits is

$p(1) = 7p(1-p)^6$, where p is the bit error rate

The probability of more than one bit in error is

$$\begin{aligned} p(>1) &= 1 - \left[p(0) + p(1)\right] \\ &= 1 - \left[(1-p)^7 + 7p(1-p)^6\right] \\ &= 1 - \left[(1-p)^6(1+6p)\right] \end{aligned}$$

For $p = 10^{-4}$,

$$p(1) = 7.0 \times 10^{-4}; \quad \frac{p(>1)}{p(1)} = 3.0 \times 10^{-4}$$
$$p(>1) = 2.1 \times 10^{-7}$$

for $p = 10^{-3}$,

$$p(1) = 7.0 \times 10^{-3}; \quad \frac{p(>1)}{p(1)} = 3.0 \times 10^{-3}$$
$$p(>1) = 2.1 \times 10^{-5}$$

This shows that, to a reasonable approximation, multiple errors may be neglected.

The Vicom specification limit on crosstalk, under test conditions, which can be expected to approximate in-service observed idle channel noise, is 25 dBrnC0, which is quivalent to -63 dBm0. This corresponds to an rms level of 0.0005, and exercises the two least significant bits. Exercising the fourth least significant bit would occur with a probability of 10^{-4}, assuming a Gaussian density function. Since the sampling rate is 8000 times per second, idle channel noise will trigger this bit roughly once per second. Thus, if the binary word representing the amplitude of a PAM sample for an idle channel is perturbed by an error in the first three bits, the amplitude of the resulting pulse can be expected to have the amplitude distribution of idle channel noise across the large segment to which the error converted the signal. This is shown, qualitatively, in Figure B-2.

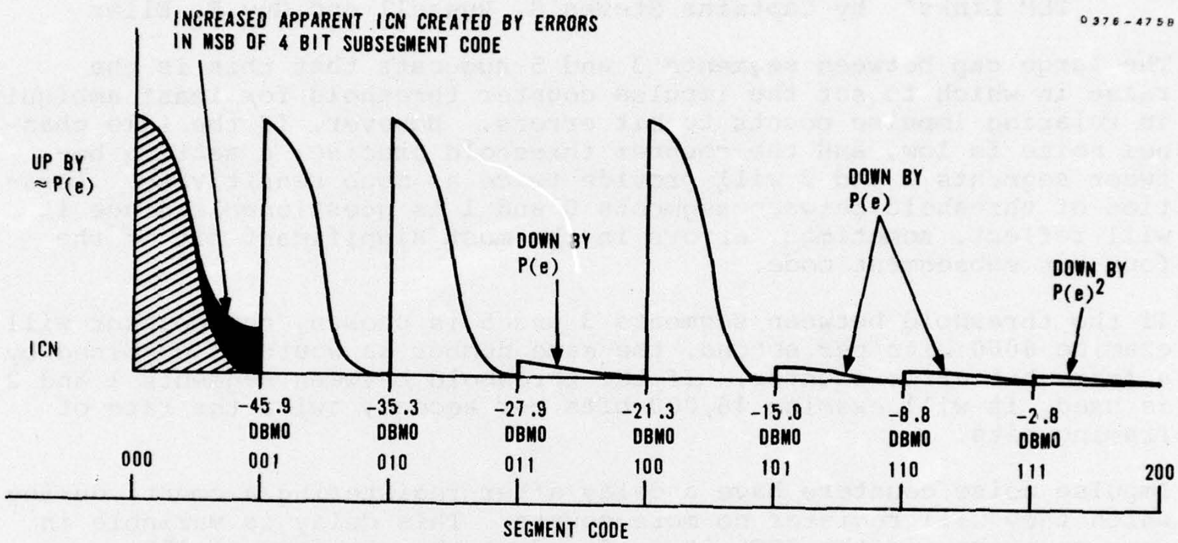

FIGURE B-2. EXPECTED PROBABILITY DISTRIBUTION OF PULSES PRODUCED BY ERRORS IN IDLE CHANNEL

B-5 INFERRING DIGITAL ERRORS FROM IMPULSE NOISE COUNTS

The effects shown in Figure B-2 have been observed qualitatively in experiments made by both AFCS(a) and RADC(b).

a. "DCS Operational Test and Evaluation of DCM/TDM Equipment" August 1973 - December 1971

b. "Performance of Selected Quasi-Analog, Synchronous and Non-Synchronous Date Transmission Schemes on Non-Error-Free TDM Links" by Captains Steven S. Russell and Guy E. Eller

The large gap between segments 3 and 5 suggests that this is the range in which to set the impulse counter threshold for least ambiguity in relating impulse counts to bit errors. However, if the idle channel noise is low, and the counter threshold precise, a setting between segments 1 and 2 will provide twice as much sensitivity. Location of threshold between segments 0 and 1 is questionable since it will reflect, sometimes, errors in the most significant bit of the four-bit subsegment code.

If the threshold between segments 3 and 5 is chosen, the counter will examine 8000 bits per second, the same number as would be examined by a frame bit error counter. If the threshold between segments 1 and 2 is used, it will examine 16,000 bits per second, twice the rate of framing bits.

Impulse noise counters have a delay after registering a count, during which they will register no more counts. This delay is variable in some counters; in the IQCS it is fixed at the standard of 150 milliseconds.

Under the assumption of random errors (Poisson distribution), if only segment 5 impulses are recorded, the mean number of errors in 150 milliseconds is:

$$M = 6.4 \times 10^{-4} \times 0.15 \times \frac{1}{8} \times (BER)$$

$$= 1.2 \times 10^{-5} \times BER.$$

The probability of (s) errors is

$$p(s) = \frac{e^{-M} M^s}{s!}$$

and the probability of two or more errors is

$$p(2 \text{ or more}) = \left[1 - p(0) + p(1)\right]$$

at 10^{-3} BER p(0) = 0.30; p(1) = 0.35; p(>1) = 0.35

at 10^{-4} BER P(0) = 0.886; P(1) = 0.106; P(>1) = 0.008

From which the masking can be calculated at

$$10^{-3} \text{ BER } \frac{p(>1)}{p(1)} = 1.0$$

$$\text{at } 10^{-4} \text{ BER } \frac{(p>1)}{p(1)} = 0.057$$

Use of the delay may, however, provide more useful information than minimizing it. For instance, to an AUTODIN user transmitting 80 character blocks over a 4800 BPS modem, the block length is about 150 milliseconds. Thus, the number of impulses counted, particularly under real word conditions of non-stationary error statistics, is more relatable to blocks containing one or more errors than a straightforward error rate inference.

The I/OQCS is designed so that impulse noise may be counted on a channel which is jacked in (as opposed to the input coming through scanners), without interfering with other I/OQCS functions.

B-6 INFERRING DIGITAL ERROR RATE FROM IDLE CHANNEL NOISE

It is plausible to consider inferring digital error rate from the increase in idle channel noise which results from errors in the digital stream.

The theoretical relationships should first be determined.

If the second order possibilities of more than one bit in error or of a bit in error decreasing idle channel noise are ignored, the average energy contribution, relative to full A-to-D converter range is:

$$E_{ER} = \frac{1}{8} \sum_{i=1}^{8} e_i^{\,2} = 4.82 \times 10^{-4}$$

where e_i is the contribution of the i^{th} bit when it is "1"

E_{ER} is the average contribution of a bit in error

When properly adjusted, the PCM system just reaches its full scale (all 1;s in the amplitude bits) on a 0 dBm sine wave. The energy above must be converted so that it is relative to the root-mean-square amplitude of a sine wave of that magnitude.

$$E_{RM} = E_{ER} \times (1.414)^2$$

$= 9.64 \times 10^{-4}$ fraction of the MS energy of the pulses constituting a sine wave to full amplitude

The power added by noise is the noise energy per second. To convert to power, it is necessary to divide by the sample rate, and multiply by the numb r of errors per second

$$P_E = 9.64 \times 10^{-4} \times \frac{1}{8000} \times EPS$$

$$= 1.2 \times 10^{-7} \times EPS$$

One error per second corresponds to 1 error in 64,000 bits, so

$$P_E = 1.88 \times 10^{-2} \times BER$$

This relationship is the slanting line in Figure B-3.

The "idle channel noise" of the Vicom D-2, with all channels terminated is specified as -65 dBm0. "Crosstalk", which is defined as the leakage of a 0 dBm0 tone into any other channel is a more realistic limit for a single idle channel in a bank of multiplexers in service. This is specified as -63 dBm0, and is the horizontal line in Figure B-3. The composite curve of error noise and multiplex noise is the curved line.

Most measured curves of ICN versus BER do not follow this theoretical curve. Three obvious reasons for a difference exist; difference in individual equipment characteristics; effect of multiple errors, which becomes noticeable at 10^{-3}, and use of different reference levels.

A more fundamental reason also exists. Noise due to errors is an impulse pheonomenon, but noise measuring sets are designed to measure signals with a reasonably well behaved amplitude distribution. The single bit error which contributes most to error noise (first amplitude bit) is 100 times (40 dB) above the rms amplitude of the equipment noise. Normal operation of test sets does not require this dynamic range; they saturate. Response is thus a function of unspecified equipment characteristics.

The IQCS in its power measurement mode, will autorange. As currently programmed, the IQCS starts ranging on the highest gain, using 10 ms samples. Any overflow in the A/D converter will cause a 6 dB decrease in gain. Once a 10 ms sample without overflows is found, measurement begins. However, any overflow within the measurement period causes the device to reinstitute the measurement with 6dB less gain.

The IQCS will thus give a true measurement of what appears in its 1.6 second level measurement window. What appears in that window is, however, subject to the small sample effect, and is thus not a valid indicator of error performance.

What emerges from these considerations is that the effect of bit errors in a PCM system is fundamentally of an impulsive nature. If digital degradation is to be measured by its effects on the analog signal, impulse sensitive devices should be used.

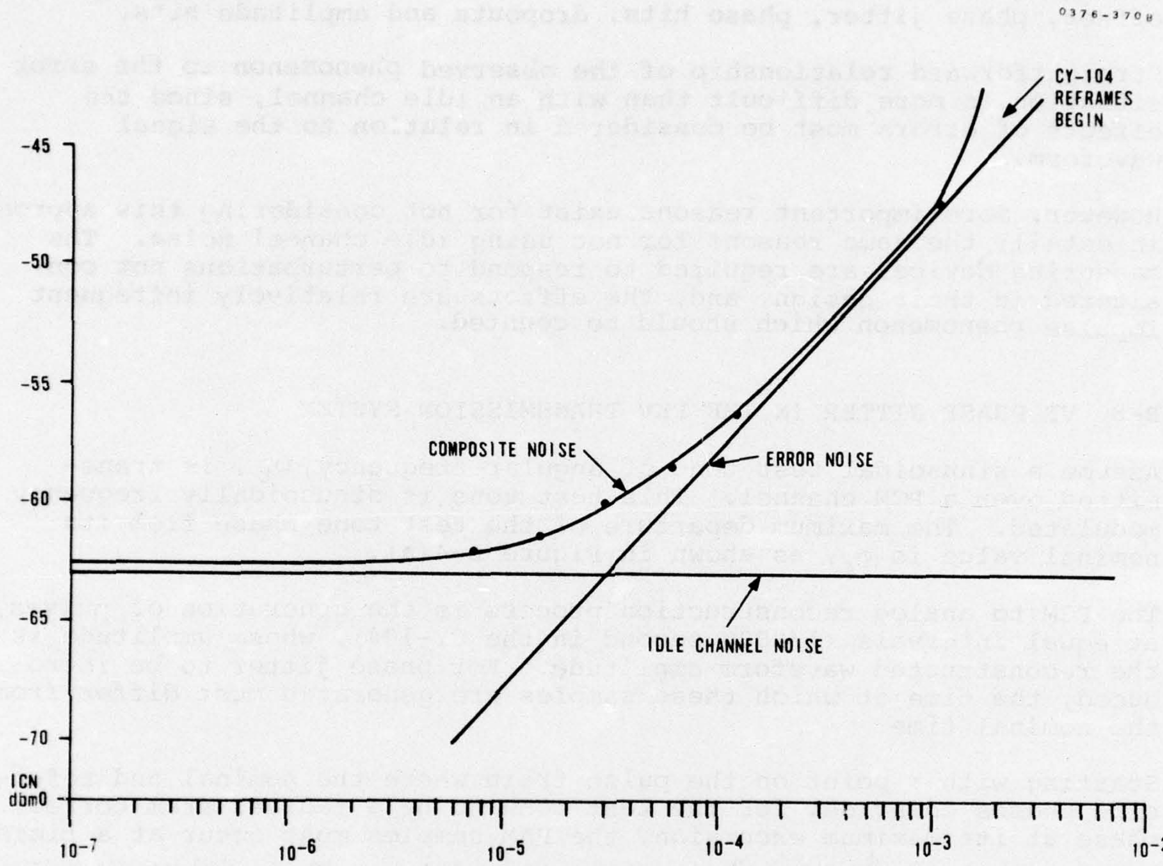

FIGURE B-3. THEORETICAL IDLE CHANNEL NOISE VERSUS BIT ERROR RATE

B-7 MEASUREMENTS MADE UPON A SIGNAL

Measurements performed with a signal in the channel include frequency offset, phase jitter, phase hits, dropouts and amplitude hits.

Straightforward relationship of the observed phenomenon to the error situation is more difficult than with an idle channel, since the effects of errors must be considered in relation to the signal waveform.

However, more important reasons exist for not considering this approach in detail; the same reasons for not using idle channel noise. The measuring devices are required to respond to perturbations not considered in their design, and, the effects are relatively infrequent impulse phenomenon which should be counted.

B-8 VF PHASE JITTER IN THE FKV TRANSMISSION SYSTEM

Assume a sinusoidal test tone of angular frequency, ω_t , is transmitted over a PCM channel. This test tone is sinusoidally frequency modulated. The maximum departure of the test tone phase from its nominal value is ϕ_t, as shown in Figure B-4(a).

The PCM to analog reconstruction process is the generation of pulses, at equal intervals (1/8000 second in the CY-104), whose amplitude is the reconstructed waveform amplitude. For phase jitter to be introduced, the time at which these samples are generated must differ from the nominal time.

Starting with a point on the pulse train where the nominal and reference phases coincide, for the test tone to be ϕ radians from correct phase at its maximum excursion, the PAM samples must occur at a timing offset equal to $\frac{\phi}{\omega_t}$ from their nominal position. This occurs in 1/4 cycle of the modulating tone, a time of $\frac{\pi}{2\omega_j}$ seconds. Figure B-4 shows the situation, and nomenclature used.

If sinusoidal frequency modulation is assumed so that the sample timing values sinusoidally, then

$$\omega_s = \omega_o \, (1 + \alpha \sin \omega_j \, t)$$

where $\omega_s \triangleq$ instantanious sample frequency

$\omega_o \triangleq$ nominal sample frequency

$\alpha \triangleq$ fractional peak frequency deviation

The phase of the PAM sampling signal may be expressed as

$$\phi = \int \omega_s \, dt = \int \omega_o \, (1 + \alpha \sin \omega_j \, t) \, dt$$

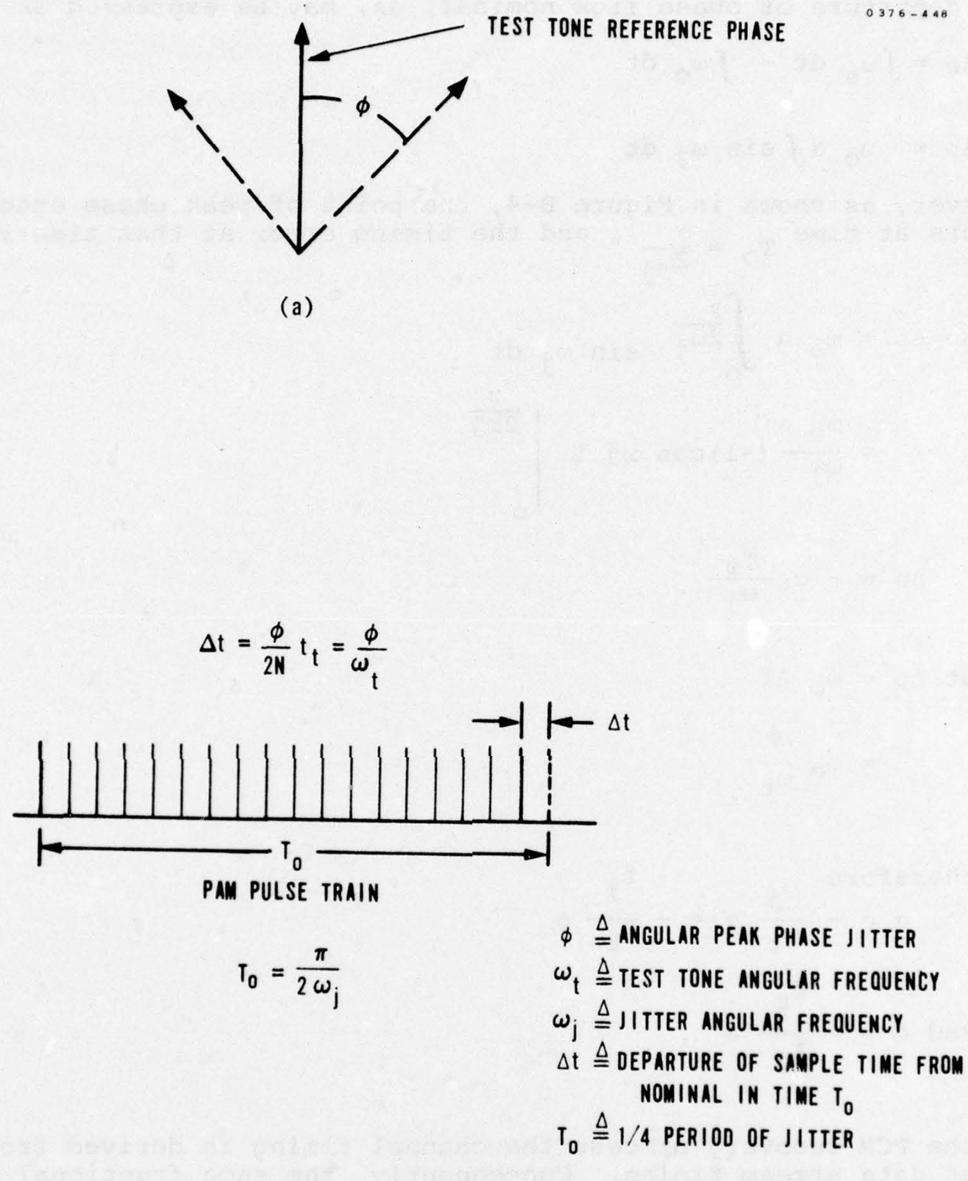

FIGURE B-4. MAXIMUM DEPARTURE OF THE TEST TONE PHASE FROM ITS NOMINAL VALUE

The departure of phase from nominal, $\Delta\rho$, may be expressed as

$$\Delta\rho = \int \omega_s \, dt - \int \omega_o \, dt$$

$$\Delta\rho = \omega_o \, \alpha \int \sin \omega_j \, dt$$

However, as shown in Figure B-4, the point of peak phase excursion occurs at time $T_o = \frac{\pi}{2\omega_j}$, and the timing error at that time is $\frac{\phi}{\omega_t}$

$$\text{so } \Delta\rho = \omega_o \, \alpha \int_o^{\frac{\pi}{2\omega_j}} \sin \omega_j \, dt$$

$$= \frac{\omega_o \, \alpha}{\omega_j} (-1) \cos \omega j \, t \Big|_o^{\frac{\pi}{2\omega j}}$$

$$\Delta\rho = - \alpha \frac{\omega_o}{\omega_j}$$

$$\text{but } \Delta\rho = \omega_o \, \Delta T$$

$$= \omega_o \frac{\phi}{\omega_t}$$

therefore

$$\alpha = - \frac{\omega_j}{\omega_t} \phi = - \frac{f_j}{f_t} \phi$$

$$\text{and } \phi = - \frac{f_t}{f_j} \alpha$$

In the PCM recovery process the channel timing is derived from the input data stream timing. Consequently, the same fractional errors will exist in both.

In the T1-4000 multiplexer the fractional allowable departure of T-1 rates, within which bit stuffing is operable, is approximately 10^{-4}. Using this value of α; a jitter frequency of 100 Hz and a test frequency of 1 KHz in the equation,

$$\phi = - \frac{f_t}{f_j} \alpha$$

leads to $\phi = 10^{-3}$, equivalent to about 1/3 degree.

The implications of these relationships are that timing problems in the transmission system will drive the T1-4000 well beyond its bit stuffing limits before any significant VF channel jitter can be introduced.

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